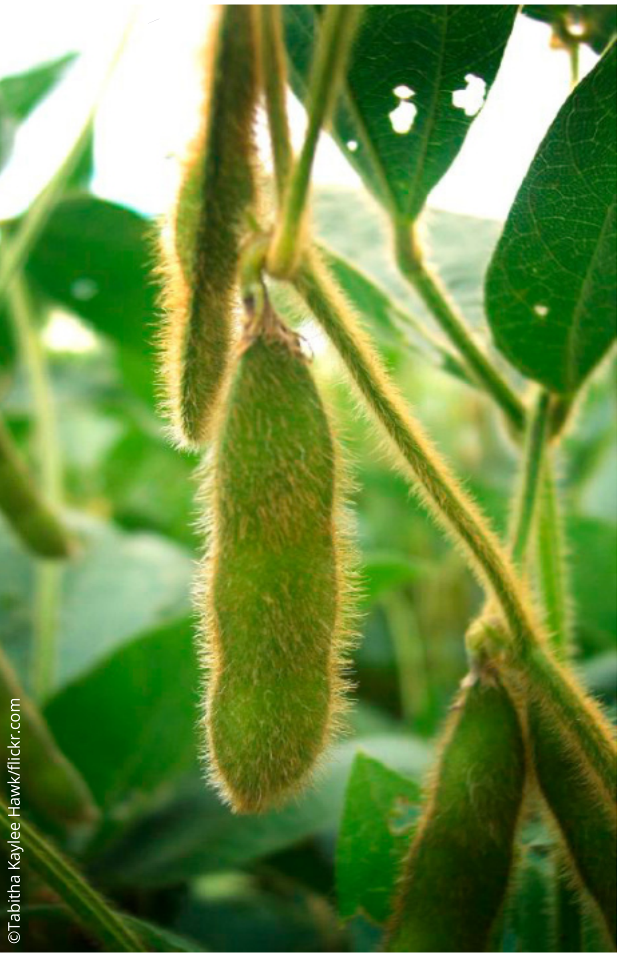
CLIMATE RISK PROFILE SERIES

ADAPTING GREEN INNOVATION CENTRES TO CLIMATE CHANGE: ANALYSIS OF VALUE CHAIN ADAPTATION POTENTIAL

Cassava, peanut, and soya bean value chains in the Central Region of **Malawi**



©Tabitha Kaylee Hawk/flickr.com

©Mariola Acosta, Research Fellow IITA/CCAFS

©www.freepik.com

Alliance Bioversity International CIAT

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

CGIAR Research Program on Climate Change, Agriculture and Food Security CCAFS

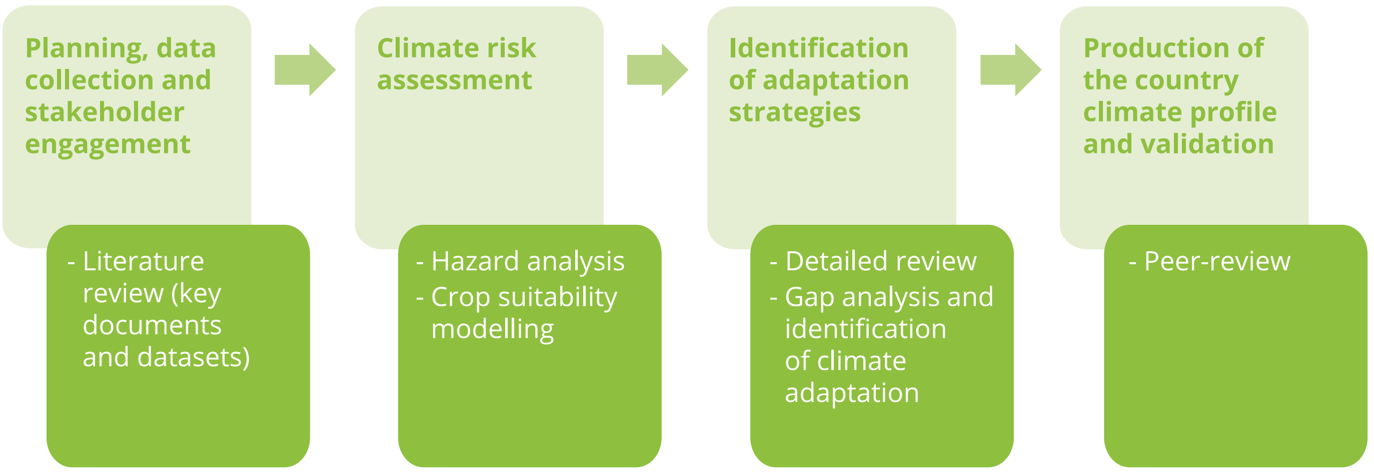
ABOUT THIS REPORT

Climate change is affecting agriculture more than any other sector. Increased frequency and severity of drought, flood, heat, and unseasonable rainfall heavily impact rainfed agriculture, ultimately resulting in production losses. In that context, The Alliance of Bioversity International and the International Center for Tropical Agriculture (CIAT) through its climate action lever, are developing climate risk profiles for agricultural value chains in developing countries at the national and subnational level. These profiles build on past work conducted by CIAT and the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)in collaboration with the World Bank and other partners, including FAO, USAID, DFID[1].

The present report aims to provide a climate and vulnerability analysis of the Green Innovation Centres (GIC) target commodity value chains. Herein we identify climate change- related vulnerabilities, hazards, and opportunities for adaptation to the same. Ultimately, our goal is to foster awareness of risks and adaptation priorities in the selected value chains and inform climate investments and planning through the recommendations on priority innovations to manage climate risks.

The report begins with an extensive literature reviews of the selected value chains and their key challenges and adaptation strategies. Climate hazards and crop suitability modelling offer insights into potential future scenarios under climate change. These results inform potential adaptation approaches, which are prioritized by in-country experts and stakeholders through an online survey. The top-rated adaptation priorities undergo a cost-benefit analysis. Finally, the results are peer-reviewed by the GIC country office and the Alliance scientific staff.

The **Green Innovation Centres** for the Agriculture and Food Sector (GIC) founded by German Federal Ministry for Economic Cooperation and Development (BMZ) and led by the German Agency for International Cooperation (GIZ) in collaboration with local ministries and programmes, aims to promote agricultural innovation under the *ONEWORLD No Hunger* initiative. Through the GIC, GIZ aims to generate employment raise farmers' income, and improve farmers' education and skills by funding training in good agricultural practices, water management, post-harvest processing, and entrepreneurship.



1 https://ccafs.cgiar.org/publications/csa-country-profiles

HIGHLIGHTS

- » Local seed production is popular among farmers since its cost effective and readily available making adoption of improved seed varieties relatively low among farmers **(Chapter 2, pg.16).**
- » Barriers to agricultural development and climate adaptation are low input use, high costs of agriculture inputs, poor access to agro-weather information, limited knowledge of innovative technologies, land degradation, and poorly coordinated efforts by farmer cooperatives **(Chapter 2, pg.16-17).**
- » High poverty rates, poor literacy levels, inadequate access to basic needs are underlying compounding issues affecting the cassava, peanut and soyabean farmers in Malawi but cost effective, low-risk strategies are available to improve resilience within the cassava, peanut, and soya bean value chains **(Chapter 5, pg.27-28).**
- » The use of improved seeds is rated the most efficient adaptation strategy across the prioritised value chains attributable to a higher internal return rate and a short payback period and its ripple benefits across the other value chain stages **(Chapter 6, pg.37-38).**
- » Conclusively the adaptation potential for the selected value chains is promising. However investing in an enabling environment is an essential prerequisite for the transformation of the cassava, peanut, and soya bean value chains **(Chapter 7, pg.40).**

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS AND ABBREVIATIONS

ADMARC	Agricultural Development and Marketing Corporation
AEZs	Agro-Ecological Zones
AGRA	Alliance for a Green Revolution in Africa
AISL	Agro-Input Suppliers Limited
ATCC	Agricultural Technology and Clearing Committee
BAU	Business as Usual
BMZ	German Federal Ministry for Economic Cooperation and Development
C:AVA	The Cassava: Adding Value in Africa
CBA	Cost Benefit Analysis
CDD	Consecutive Dry Days
CDI	Clinton Development initiative
CIP	International Potato Center
CSA	Climate-Smart Agriculture
DARS	Department of Agricultural Research Services
FUM	Farmers Union of Malawi
GAP	Good Agriculture Practices
GDP	Gross Domestic Product
GHG	Green House Gas
GIC	Green Innovation Centers
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
ICRISAT	International Crop Research Institute for the Semi-Arid Tropics
IITA	International Institute of Tropical Agriculture
IRR	Internal Rate of Return
LGP	Length of Growing Season
MGDS	Malawi Growth and Development Strategy
MPRS	Malawi Poverty Reduction Strategy
MWK	Malawi Kwacha
NAP	National Agriculture Policy
NAPA	National Adaptation Programme of Action
NASFAM	The National Smallholder Farmers' Association of Malawi
NCCIP	National Climate Change Investment Plan
NCCM	National Climate Change Management
NDRM	Natural Disaster Risk Management Plan Malawi
NDWS	Number of Days with Moisture Stress
NEP	National Environmental Policy
NGO	Non-Governmental Organizations
NPV	Net Present Value
RCP	Representation Concentration Pathway
SGLP	Start of Growing Season
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
USD	United States Dollar

1. INTRODUCTION

Malawi is a landlocked country situated in Southern Eastern Africa. As laid out in Malawi Vision 2020,[2] the nation envisions a state where its entire population has year-round access to food that is safe and adequate to meet their nutritional requirements. To achieve this, Malawi's government aims to address strategic areas including increasing food production, developing irrigation, developing the livestock sub-sector, improving the efficiency of markets, reducing post-harvest losses, improving disaster management, improving land utilization and management, economically empowering vulnerable groups, promoting non-farm income-generating activities, and improving the population's nutrition status. Unfortunately, even with its natural resource base, abundant water resources—including Lake Malawi, Africa's third largest freshwater lake—and a tropical climate, progress towards these goals is hindered by increasing climate variability and its associated risks. The dependency on rain-fed, smallholder farming renders Malawian agriculture highly susceptible to extreme climatic hazards, a situation that calls for adaptive measures and the implementation of innovative climate-smart approaches that address the interlinked challenges of food insecurity and climate change.

In line with the national vision, the German Federal Ministry for Economic Cooperation and Development (BMZ) has commissioned Green Innovation Centers (GIC) for the agriculture and food sector as part of the "ONE WORLD – NO HUNGER" initiative in Malawi. In Malawi, the GIC is by the GIZ and supported by the Natural Resource College and Mwimba College of Agriculture. It focuses on the soya, peanut, and cassava value chains in the Central Region (Figure 1) and specific districts in the Southern and Northern regions. The GIC works with smallholder farmers, small- and medium-sized enterprises, youth- and woman-led startups, and the private sector to develop inclusive market models. Through targeted training in good agricultural practices like soil and water conservation, post-harvest management, and marketing and business knowledge, they promote the entire value chain.

This document presents the climate risk assessment for Malawi with a focus on the Central Region and three value chains, namely, cassava, peanut, and soya beans. A brief yet comprehensive document, its aim is to inform value chain stakeholders, policymakers, and the private sector about the climate change risks, vulnerabilities, and opportunities in the peanut, cassava, and soya bean value chains in Malawi. Intended to facilitate the integration of context-specific adaptation strategies and present climate-smart agriculture (CSA) investment opportunities.

This profile is organised into six sections, each reflecting an essential analytical step in understanding current and potential adaptation options for the selected value chain commodities. The first describes the importance of agriculture to people's livelihoods in the four departments. Section two highlights the policies, strategies, and programs implemented in the three value chains that address climate change, while the third section discusses the governance and institutional resources and capacity. The fourth section discusses the main climatic hazards affecting the three value chains and presents climate modeling results for projected climatic change-related hazards and crop suitability maps. Additionally, it offers an analysis of vulnerabilities and risks posed by these hazards to the respective value chains. The ongoing on-farm adaptation strategies adopted by farmers to cope with these hazards as well as the cost benefit analysis results are discussed in the fifth section. The sixth section provides a synthesis and recommendations.

2 The Vision 2020 was replaced recently by the Vision 2063

Figure 1. Map of the selected region in Malawi

Malawi is located in Southeastern Africa, south of Tanzania, east of Zambia and south and west of Mozambique. The region of study is the Central region.

2. AGRICULTURAL CONTEXT

KEY MESSAGES

- Agricultural activity is a key part of the Malawian economy, and most Malawians are involved in farming in some way.
- Agriculture is a key component of the Malawian economy, generating a revenue of 260 million USD, contributing 26% of the national GDP, employing 85% of the population, and supplying 70% of the manufacturing sector's raw materials.
- Poverty and food insecurity are endemic in Malawi, suggesting potentially great benefits from the implementation and scaling of CSA practices.
- Malawian agriculture is characterized by generally low use of inputs.
- Gendered differences are apparent in men and women's participation in agricultural activity: while men lead in livestock and cash crop production, women predominate in the growing of food crops.
- The cassava, soya bean, and peanut value chains were selected for this study because of their importance to Malawian agriculture and their nutritional profiles.
- The value chains of cassava, peanuts, and soya beans are particularly attractive for climate-smart agricultural strategies, given their importance as common, nutrient-dense local food sources and, in the case of soya, as export commodities.
- Agriculture in Malawi is challenged by both environmental and (irregular rains, land degradation) and social (disincentivized development of new seed varieties, fluctuating prices, low extension coverage) issues.
- A disproportionate number of Malawians face inflated food prices.

2.1. Economic relevance of farming

The Central Region of Malawi covers a total land area of 35,641 km² and has nine districts: Dedza, Dowa, Kasungu, Lilongwe, Mchinji, Nkhotakota, Ntcheu, Ntchisi, and Salima (National Statistical Office, 2019). The Central Region lies on a plateau, bordering Zambia to the east and Mozambique to the southwest. Dominant physical features of the Central Region include the East African Rift Valley and Lake Malawi.[3] Its capital city, also the national capital, is Lilongwe.

Agriculture is central to Malawi's economy. It contributes 26% GDP (World Bank, 2017), employs a vast majority of the population (85%), supplies 70% of raw materials for the local manufacturing sector, and generates a total revenue of approximately 260 million USD (National Statistical Office, 2016/17). Furthermore, it contributes over 80% of Malawi's foreign exchange, primarily from cotton, peanuts, tea and tobacco (National Statistical Office, 2020; WTO, 2020).

3 https://www.nationsonline.org/oneworld/map/malawi-administrative-map.htm

2.2. People and livelihoods

According to the Malawi Population and Housing Census of 2018,[4] the total national population was 17,563,749. The Central Region is the second most populous, representing 43% of the national population with 7,526,160 people (National Statistical Office, 2019). Males comprise 49% of the population of the Central Region, and females account for 51%. Of Malawi's three regions, the Central had the highest growth rate, 3.1% per annum, over the 2008-2018 period. Its rural population was 6,224,555 (83%) with an average of 4.4 persons per household.

Unfortunately, poverty levels remain high. Over half of the Malawian population is impoverished[5]. Of this, 60% reside in rural areas and 42% in Central Region. Overall, Malawi has high levels of food insecurity[6] (61%), which is more prevalent in female-headed households (69%) and rural areas (66%) (National Statistical Office, 2019). Similarly, in the Central Region, 65% of households reported inadequate food consumption and poor nutrition. The prevalence of stunting among children under the age of five was 37%, of wasting was 3%, and 12% of children were underweight (National Statistical Office, 2015/16).

Many people in the Central Region rely on farming as their main economic activity and livelihood. Agriculture in this region involves the production of major food crops (e.g., maize, rice, and cassava), tobacco and sugarcane processing, cotton and rice farming, fishing, and livestock rearing. 73% of the population aged 15-64 is employed in the agriculture, forestry, and fishing industries. Among women who work, 80% are in agriculture, while 64% of working males are employed in agricultural industry (National Statistical Office, 2019).

The literacy level in Malawi is high. 72% of population aged 15 years and above in the Central Region is literate, generally attributable to primary school enrollment of 86%. Of 1.7 million total households in the Central Region, 49% had a mobile phone and 10% had access to the internet. Access to the radio and television was at 31% and 10%, respectively. Common means of transportation in the region are bicycles (most common at 35%), motorcycles or scooters, motor vehicles, oxcarts, and boats or canoes (National Statistical Office, 2019).

Batteries are the main source of energy, used for lighting in most households in Central Region (54%), followed by electricity (9%), and solar (7%). The main source of energy used for cooking was firewood (78%), followed by charcoal (18%) and electricity (2%). Access to improved water sources, including piped water, public standpipes, tube or protected wells, and boreholes is relatively high (84%), with the main source being boreholes (60%) (National Statistical Office, 2019).

2.3. Agricultural activities

Agricultural production happens mainly on customary land, which accounts for 65% of Malawi's total land (Malawi Government, 2008). The dominant farming systems are small-scale farms and estates. In the Central Region, many farms consist of small-sized plots; the average cultivated area is 1.9 acres (Figure 2). Land ownership shows gendered differences: female managers exclusively own about 27% of the plots, while male managers own 30%. 20% are jointly owned by both female and male managers (National Statistical Office, 2016/17). Plots not owned by a specific manager are 23% (IHS4, 2016/17). Although they are resource-poor, smallholder farmers cultivate about 4.5

4 http://www.nsomalawi.mw/images/stories/data_on_line/demography/census_2018/2018%20Malawi%20Population%20and%20Housing%20Census%20Main%20Report.pdf

5 http://www.nsomalawi.mw/images/stories/data_on_line/economics/poverty/Malawi%20Poverty%20Report%20-%202019%20.pdf

6 **Very low food security**- Households experience multiple indications of disrupted eating patterns and reduced food intake. They report reduction in food quality, variety, quantity and frequency of food consumed. Consumption by adults could have been restricted in order for small children to eat and could depend on food assistance from relatives or friends (IHS4, 2016/17).

million hectares, primarily for subsistence. Maize, cassava, sorghum, sweet potato, rice, beans, and potatoes are predominantly cultivated for local consumption while export crops include tobacco, cotton, sugar, coffee, and peanuts (Malawi Government, 2008). The main types of livestock are goats, pigs, cattle, sheep, and chickens and other poultry. In the Central Region, 32% of households raise chickens, 19% have goats, and 13% have other poultry (13 %) (National Statistical Office, 2019).

Women farmers are heavily involved in the production of food crops (AGRA, 2020) while men dominate cash crops and livestock production. Women perform 70% of agricultural activities and yet they seldom control yields or farm incomes. In Malawi, women own only a third of agriculture land and on average their farm plots are 12% smaller and 25% less productive compared to the men (UMFULA, 2018). The predominance of patriarchy has often put the women in a disempowered position, hindering access and control over key productive resources. Underlying issues like social norms, literacy levels, economic dependence, geographical location and poor governance widen existing gender inequalities.

Generally, the use of inputs in the Central Region of Malawi is low. Most farm plots applied inorganic fertilisers (54%); 40% applied no fertilizer, and only 18% used organic fertilisers. Only 2% of farmers used chemical pesticides and herbicides, and the use of irrigation was almost nonexistent. 85% of households still used hoes, machetes, or knives as their major agriculture equipment. Most of the labor inputs came from members of the household (family labor), while some were hired or exchanged. Overall, 95% of women, compared to 83% of men, contributed to agricultural labor. In Central region specifically, 87% of men and 96% of women contributed to agricultural labor at the household level; hired labor comprised 10%, while exchanged labor[7] accounted for 11% (IHS4, 2016/17).

2.4. Agricultural value chain commodities

2.4.1. Cassava

Cassava (*Manihot esculenta*) is a key staple crop, coming second only to maize for almost 40% of Malawians (Chipeta, 2013). It is rich in carbohydrates, calcium, vitamins, and essential minerals. It is therefore clear that cassava is significant as a food source for nutritional and even economic security in Malawi. Smallholder farms, cultivating the crop at the subsistence level, dominate cassava farming in Malawi, making up 70% of production, while the rest (30%) is produced by few estates located in the western shores of Lake Malawi (Kocke, 2019). Women predominate in the production activities of planting, harvesting, and postharvest processing, but certain responsibilities are shared by men (e.g., tillage or land clearance) due to the hard labor involved (Kaitano and Martin, 2009).

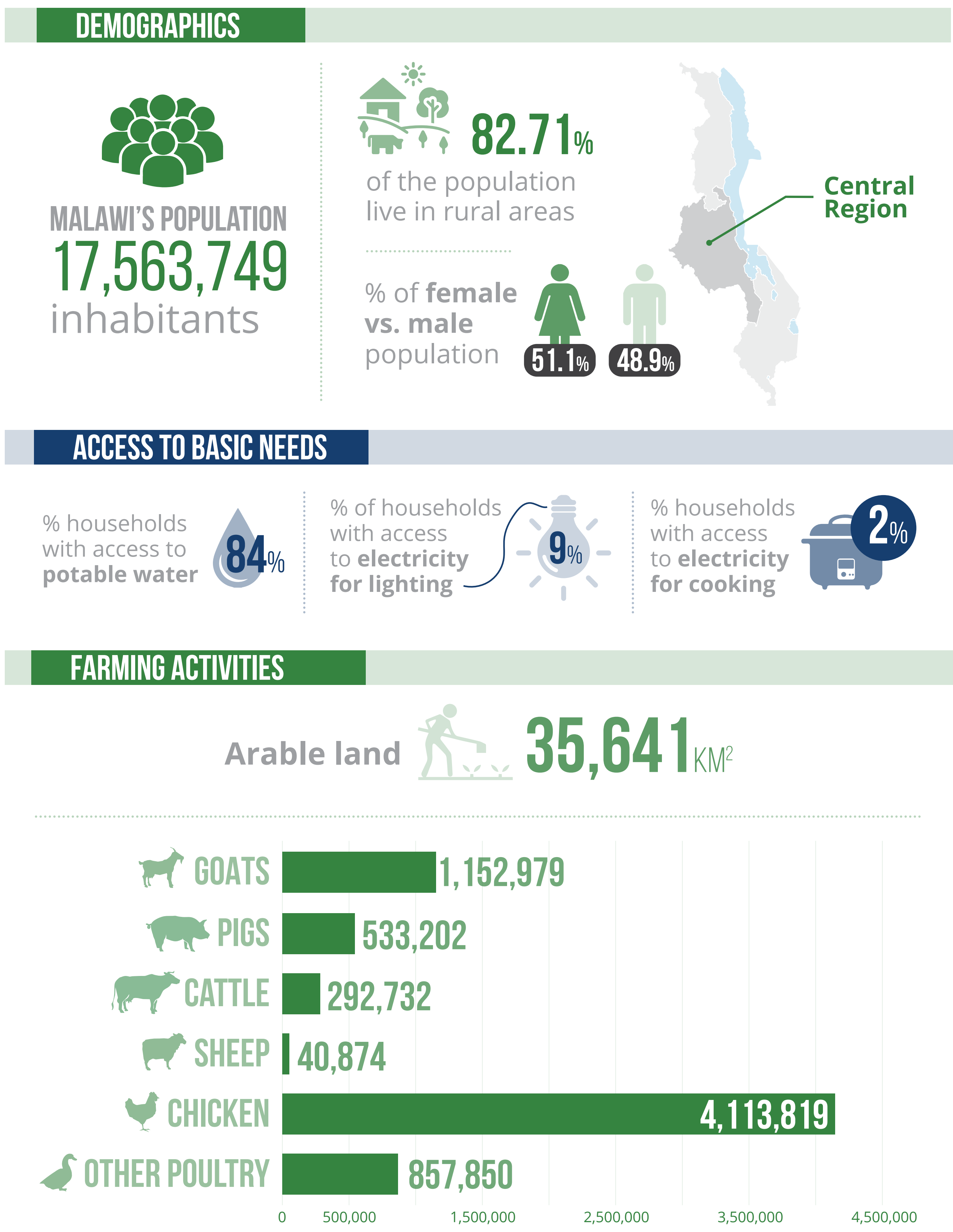
Low water requirements enable established cassava to flourish in zones receiving at least 400mm average annual rainfall and withstand prolonged dry spells (Kocke, 2019). However, cassava does best in areas receiving at least 1000mm average annual rainfall with mean temperatures between 25°C-30°C. Cassava is particularly sensitive to frost; it requires hot and humid conditions and well-drained, sandy loam, fertile soils[8].

Cassava farming depends on the supply of quality planting materials, namely seeds and stem cuttings. Stem cuttings are mainly sourced from farmers own fields. Key on-farm activities include proper land preparation; planting, weed, pest, and disease control; and harvesting. Immersion of stem cuttings in hot water or treatment with chemicals to control pests and

7 Labor that is exchanged for cash or in-kind payments like food items (e.g., maize grains).

8 https://www.mamachakula.com/uploads/5/1/2/6/51260451/cassava_growing_training_manual_final_draft.pdf

Figure 2. Livelihoods and agriculture



diseases precedes planting. Common cassava field pests are mealy bug, scales and termites while major diseases include cassava mosaic, bacterial blight and brown streak (Mathieu et al, 2009). To ensure the starch content is very high in the roots, harvesting is done during the dry season. Key activities in post-harvest processing include soaking the peeled roots, cutting or grating, drying, and milling the roots into flour. There are two main types of cassava: sweet and bitter. Many of the steps that transform cassava roots into flour are inherited household knowledge, including the treatment of bitter cassava varieties to render them fit for consumption (Kocke, 2019). Sweet cassava is often eaten raw; smaller pieces can also be fried as chips in oil (*gado*); the flour is used to make a porridge called *nsima*; the roots are boiled, brewed into beer, or used in stews such as *futali*. Sun dried roots (*makaka*) from bitter varieties are traditionally milled to semi fermented cassava flour used to make *nsima*. At the industry level, cassava starch is processed into sweeteners, thickeners, dextrin, and pastes. Cassava silage has further use as animal feed. Over the period 2017-2018, the average market prices for cassava roots was relatively higher the Southern Region, represented by Blantyre (MWK 401/kg), while in the Central Region they were almost half the price in Lilongwe (MWK 204).

Cassava production in Malawi has considerably expanded. This is due to considerable efforts by the government, non-governmental organizations (NGOs), the private sector, farmer groups and associations, civil society, and academic research institutions. Research organizations and the private sector, in conjunction with farmers, have developed new seed varieties with improved traits for the market. Other major stakeholders and actors include small and medium aggregators and processors who are important links between farmers and large-scale processors and traders.

2.4.2. Peanut

Peanut, also called groundnut, *(Arachis hypogaea L.*) is a valuable legume crop in Malawi. It is widely grown by smallholder farmers for its food and economic value (Penrhys-Evan, 2018). Peanuts are an essential source of protein, vegetable oil, and minerals in the Malawian diet. The major producing areas are in the plateau areas of Lilongwe and Kasungu (Central Region) and Mzimba (Northern Region). Peanut production is mostly at the subsistence level and is and dominated by small-scale, resource-poor farmers—especially women (Cuddeford, 2013).

Peanuts are mildly drought-tolerant since they can thrive despite low rainfall and warm conditions. However, they require at least 500-600mm of well-distributed rainfall over the growing season and temperatures in a range of 28-30°C, as lower temperatures may affect crucial crop development stages such as flowering (Cuddeford, 2013). Peanuts prefer to be cultivated below 1500 meters above sea level. While there are numerous groundnut varieties, the most common are CG7, *Chalimbana, Nsinjiro, Kakoma,* and *Malimba*.[9] Farmers get an average yield of 1000kg/ha for CG7 and *Nsinjiro* varieties and 600kg/ha for *Chalimabana* (Cuddeford, 2013).

Input supply is a crucial stage for groundnut farming as it involves sourcing of quality seed and materials for planting. This includes buying fertilisers and chemicals such as pesticides and herbicides. Many farmers use seeds retained from previous harvests, while a few buy certified seeds from credible vendors. Both men and women participate in land preparation, weeding, and banking during on-farm production; women mostly do harvesting and post-harvest processes like drying and shelling while marketing activities, like selling to traders, are done by men (Cuddeford, 2013). Peanuts are cooked, roasted for whole consumption, or processed into powder and oil. Most of the peanut crop (60%) is eaten at home, while 25% goes to processors, wholesalers, and retail markets, and 15% is exported (Cuddeford, 2013).

As a crop with a long history in Malawi, many of the actors and stakeholders in the value chain are involved in groundnut development and addressing farmers' production challenges. Variety development and breeding services are offered by governmental and non-governmental research organizations, such as the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). Farmers are represented by cooperatives and associations, such as the National Smallholder Farmers' Association of Malawi (NASFAM), increasing their bargaining powers through collective marketing (Cuddeford, 2013; Tropical Legume Farming in Malawi, 2013). These groups also facilitate linkages to agro-industries and organize fora for building farmers' capacity. There are also small- and medium-scale vendors, aggregators, and intermediaries that buy from farmers and sell to small warehouses (Matita, 2018).

2.4.3. Soya bean

The soybean or soya bean (Glycine max) is a legume widely grown for its nutritional and economic value (Kananji, et al., 2013). Soya beans are nutrient-dense, with 36% protein and 30% carbohydrates. While they are adapted to grow in all agro-ecological zones (AEZs) across Malawi, the major growing areas are Mzuzu (Northern Region), Kasungu, and Lilongwe (Central Region); together these represent 91% of the total production area. Additionally, there are many varieties of soya beans, suiting different agro-ecologies and offering high yield potentials (2500-3000kg/ha). Consequently, farmers can select varieties that are best adapted to their locations, for example choosing a fast-maturing variety in a drought-prone area. Current soya bean varieties include Makwacha, Nasoko, Ocepara-4, Tikolore, Solitaire and Soprano. Smallholder farmers primarily grow soya beans, and women are very engaged with their production, processing, and utilisation (Kananji et al., 2013). This could be explained by women's tendency to move towards edible food crops that supplement household diets (Mubichi, 2017), while men focus on production for the markets.

Soya bean is a drought-tolerant crop that does well in warm, moist conditions with well-distributed rainfall of 550-850mm and temperatures between 20-25°C over the growing season period (Kananji et al., 2013). High moisture is critical during germination. Since soya bean is a good nitrogen fixer, it likes soil that is fertile, well drained, and rich in calcium. Sourcing quality seeds, fertilisers, herbicides, and pesticides is important at the input-acquisition stage (Tropical legume farming in Malawi, 2013). The use of poor quality seeds puts farmers at risk for poor yields and high economic losses. Site selection is also important to avoid steep slopes and poor soils. Once the land is prepared, farmers' plant inoculated soya bean seeds on either ridges or flatbeds. Pest and disease control, fertiliser application, weeding, and harvesting are major activities during the on-farm production stage. Good agricultural practices (GAPs) during production assure proper crop development. The post-harvest stage has many steps, including threshing, winnowing, cleaning, separating, sorting, and grading. Soya bean storage is very important, since the conditions at which seeds are stored can greatly influence their quality and quantity. Soya bean seeds are also processed and sold as soy flour, soy protein, soymilk, oil, and animal feed.[10]

Because Malawi is among the top forty producers of soya beans globally, many actors and stakeholders are key in the value chain's development. Research organizations like the International Institute of Tropical Agriculture (IITA) and the Department

9 http://scripts.farmradio.fm/radio-resource-packs/package-97-growing-groundnuts/groundnut-value-chain-in-malawi-production/#:~:text=Although%20groundnuts%20are%20grown%20in,%2C%20Ntchisi%2C%20Dowa%20and%20Thyolo.

10 https://mitc.mw/trade/index.php/soya bean-export-product

of Agricultural Research Services (DARS) facilitate breeding, variety development, and technical training to build capacities (Tropical Legume Farming in Malawi, 2013). Farmers' associations facilitate rural seed production and multiplication and link farmers to markets. The private sector is involved in market facilitation of soya beans and their byproducts; due to increasing production, Malawi has some large-scale processors who, like Rab,[11] buy soya beans from farmers to produce human food or to make livestock feeds.

2.5. Agricultural sector challenges

A survey conducted in 2019 by the National Statistical Office on shocks that negatively affect household welfare counted unusual or exorbitant prices of food in the markets (68%), irregular rains (58%), and higher cost of agricultural inputs (46%), as key issues affecting a large proportion of Malawians. The Central Region was particularly affected by unusually high food prices (69%), unusually high costs of agriculture inputs (55%), and irregular rains (52%). While urban areas experienced more of a shock with food prices (75% compared to 67% in rural areas), rural areas reported a significantly higher proportion of population affected by irregular rains compared to urban areas (67% vs. 23%). The proportion of households that experienced at least four types of shocks was higher in rural areas, at 39%, than in urban areas 16%.

This survey helps to demonstrate the threat climate change and variability pose to an agricultural system that heavily relies on rain-fed conditions (Mubichi, 2017). Present climate-related hazards such as drought are increasingly contributing to acute food shortages in the Central Region.

There are also social reasons for these pressures. A poorly harmonized seed approval process disincentives seed companies from investing in the development of seeds and markets (Mubichi, 2017), contributing to the high cost of inputs (e.g. seeds). Agricultural knowledge flows are still quite informal, resulting in major gaps in access to agriculture information and extension services from credible sources (Kerr et al., 2018). Moreover, gendered social dynamics mean that women and men have differing access to available knowledge due to their roles in value chains activities. Fluctuating demands and low farm-gate prices, compounded by weak market infrastructures, have contributed to low incomes. Similarly, poor extension services limit access to weather information and services, practical skills development, and knowledge about processing and utilisation. Sometimes, even with the presence of cooperatives and associations, weak management structures and poor governance lock farmers out of beneficial opportunities (Lwanda et al., 2012).

Key constrains specific to soya bean production include limited access to new and improved seed varieties, high disease (soya bean rust) and pests (caterpillars) incidence, poor market access hence farmers sell at very low farm gate prices. The inadequate knowledge and capacity on soyabean processing and utilisation contributes to low incomes (Kananji, et al., 2013). Like soyabean, majority of peanut and cassava farmers also use their own seed due to limited availability and expensive nature of adapted seed varieties. Limited market opportunities due to disorganized market structures lock out farmers from directly participating in market activities (Tropical legume farming in Malawi, 2013).

11 Rab Processors is a leading player in the agriculture industry in Malawi and specializes in value addition and trading of locally grown produce. They provide farm inputs and household goods nationwide to smallholder farmers through the network of Kulima Gold Depots and they provide a vital market to farmers selling their produce.

Population growth pressures, unsustainable agriculture practices (overgrazing and deforestation), and other poor land-use (timber, fuel-wood and charcoal extraction due to the percentage of Malawians using firewood for cooking purposes) have led to serious land degradation. This has direct impacts such as increased soil erosion, leaching of soil nutrients, and salinization/alkalization, all of which decrease arable land. Deforestation also has water supply outcomes. Indirect concerns resulting from population growth and land degradation include famine and possible conflicts due to declining fertility and competition for fertile land plots (Kirui, 2016).

3. POLICIES, STRATEGIES AND PROGRAMS ON CLIMATE CHANGE

KEY MESSAGES

- » The government of Malawi has various policies and programs that support adaptation efforts directly and indirectly.
- » Direct programs aim to address climate impacts on vulnerable communities, introduce good agricultural practices, and emphasize climate-smart practice and technologies.
- » Programs aimed at poverty reduction, food insecurity, and national nutritional priorities indirectly address climate change in their focus on the use of natural resources and improving agricultural output.

The Government of Malawi has formulated various policies to support climate change adaptation and mitigation. As a signatory to the United Nations Framework Convention on Climate Change (UNFCCC), Malawi developed its Nationally Determined Contributions (NDC) to track and reduce emissions (Irish Aid, 2018). Malawi Vision 2020 is the overarching, long-term strategy framework that addresses climate change issues. There are, however, other pertinent policies, strategies, and priorities. The Malawi Poverty Reduction Strategy (MPRS 2002) mainstreams climate change into its economic development plan by ensuring the sustainable use of natural resources, promoting small-scale irrigation schemes, and improving agricultural production through research and extension (Irish Aid, 2018). The National Agriculture Policy Malawi (NAP 2016) aims to achieve agricultural transformation by prioritizing sustainable agricultural production, developing irrigation, improving value addition and processing, and agricultural risk management. The Malawi Growth and Development Strategy (MGDS II 2012–2016) prioritizes climate change, natural resources, and environmental management at the country level (Irish Aid, 2018). Under the MGDS's umbrella, the Natural Disaster Risk Management Plan Malawi (NDRM 2015) was developed to reduce disaster losses of lives and community assets. In the agricultural sphere it focuses on adaptation and mitigation measures for floods and droughts, using investments in agricultural inputs and the establishment of irrigation schemes in rural areas. The National Environmental Policy (NEP 2004) was developed to guide efforts aimed at minimizing the adverse effects of climate change, reducing pollution and greenhouse gasses (GHGs) through sound management of the environment and natural resources.

In addition to these environment- and poverty-related frameworks and strategies, the Malawian Government has developed strategic plans and policies to guide climate change adaptation programs. The National Climate Change Investment Plan (NCCIP 2003-2018) was developed to increase climate change investments in Malawi. The goal of the National Adaptation Programme of Action (NAPA 2006) is to address the impacts of climate change (particularly flood and drought) on vulnerable communities, fragile agro-ecosystems, and important sectors of economic growth (USAID, 2017). The National Climate Change Management Policy (NCCM 2016) aims to create an enabling policy and legal framework for integrating climate change management in the development plans of the country (USAID, 2017).

These policies and strategies demonstrate clear effort and commitment by the Malawi Government to address climate change challenges. They provide instruments for the growth and development of Malawi; however, some lack clear entry points and guidelines for specific areas, like agriculture, fisheries, and the forestry sector. The contribution of agriculture towards climate change adaptation and mitigation in these policies overall is brief and broad, limiting options to facilitate the implementation of new CSA approaches and technologies and creating the possibility of uncoordinated adaptation efforts. Furthermore, climate adaptation policies need to consider and incorporate local context concerns and address the multi-dimensional, dynamic, and crosscutting nature of climate change and its related risks. It is also vital that policies are aligned with existing trade and specific value chain policies to reduce overlaps and possible conflicts when implementing programs and projects at the farm level.

4. GOVERNANCE, INSTITUTIONAL RESOURCES AND CAPACITY

KEY MESSAGES

- Local and international support has boosted the adaptive capacity of farmers in Malawi.
- Soya beans have benefitted from the introduction of improved varieties, post-harvest handling and storage technologies, and education from national and international organizations.
- Peanuts have benefitted from support in the realm of aflatoxin surveillance and prevention.
- Cassava has benefited from the introduction of improved varieties and the development of post-harvest processing for value addition.
- The Government of Malawi, local organizations, and international institutions are committed to mitigating climate impacts and improving resiliency, but poor coordination and collaboration have constrained implementation efforts.

4.1. Soya beans

Farmers in the soya bean value chain have received support from IITA such as the introduction of varieties that are high yielding, biotic and abiotic stress-tolerant, and nitrogen fixing. IITA has also introduced technological advancements in post-harvest handling technologies, like soya bean mobile thresher-cleaners. In addition to sensitizing farmers to intensifying their maize-based cropping systems through maize-soya bean rotation, IITA produced a manual on improved agronomic practices for increased soya bean productivity. Agro-Input Suppliers Limited (AISL), in collaboration with the Ministry of Agriculture and farmers' representative bodies such as the Farmer's Union of Malawi (FUM) and NASFAM, is lobbying for wider dissemination of proper seed selections and the use of rhizobium inoculant to increase productivity. The Clinton Development Initiative (CDI) Anchor Farm provides soya seed inputs, loans, and credit to smallholder farmers. The Agricultural Technology and Clearing Committee (ATCC) tests and releases soya bean varieties suited for all the AEZs in the country.

4.2. Peanuts

In the peanut value chain, ICRISAT and Feed the Future encourage the cultivation of peanuts by the development of new varieties, and introduce GAPs for increased agricultural productivity. IITA has introduced technologies for the detection, assessment, prevention, and control of aflatoxins, pests, and diseases. The research of the IITA and the United States Agency for International Development (USAID) on aflatoxin management and mitigation has played a significant role in biological control of aflatoxin in fields. The Malawi Bureau of Standard is responsible to enforce the quality of peanuts and test for aflatoxin contamination. Farmers unions and associations (FUM, NASFAM) are key partners in facilitating farmer training for collective production, processing and marketing.

4.3. Cassava

Cassava farmers have received support from the International Potato Centre (CIP), which has trained them on GAPs for improved productivity, and improved storage technologies (e.g., diffuse light stores). While CIP and IITA have introduced high yielding and disease-resistant varieties, DARS has developed improved cassava germplasm through partnerships with NGOs. It also provides research on the properties of selected cassava seed varieties. Farmers World Limited specializes in the production of fertilizer blends that would potentially increase yields. The Cassava: Adding Value in Africa (C:AVA) Project widely supported farmers with planting materials.

The organizations listed above demonstrate the importance of leveraging strengths from diverse stakeholders to achieve climate adaptation and build farmer resilience. However, working with organizations that have overlapping and conflicting mandates and different institutional mechanisms can bring about conflict. For example, varietal development efforts are multifarious, and without concerted efforts, this can lead to confusion and the duplication of efforts. Unfortunately, no policy, law, or regulation yet exists to serve as a model and guide for institutional mechanisms and coordination in Malawi (Irish Aid, 2018). Open communication channels among international organizations and between relevant ministries and departments is crucial to ensuring that institutional programs are in line with the national vision, that they support existing policy frameworks on climate change and specific agricultural commodities, that resources are appropriately pooled, and that the wider community is reach. Additionally, organizations should continuously monitor and evaluate the progress of project implementation to ensure best practices and great impact on targeted beneficiaries.

5. CLIMATE CHANGE-RELATED RISKS AND VULNERABILITIES

KEY MESSAGES

- The effects of climate change, particularly increased drought and decreased rainy seasons, have negatively affected agricultural production, resulting in increased poverty and food insecurity in Malawi.
- Rainfall variability, particularly a shortening of the rainy season and an increase in consecutive dry days during the growing season, is the primary climate change risk faced by Malawian agriculture.
- Under projected climate change, the suitability of soya beans will remain stable while the suitability of peanuts and cassava will increase.
- Malawian farmers are aware of climate change, although they primarily associate it with rainfall amounts. Increased education and awareness could support their ability to cope with climate change impacts.
- Cassava, peanuts, and soya beans are all particularly susceptible to temperature increases, rainfall variations, and drought.
- Women are frequently restricted to food crop production and are granted lower access to basic farm services than men are; consequently, they are particularly vulnerable to climate impacts.

5.1. Farmers' perceptions on climate change

According to a knowledge, attitude, and practice survey conducted in Malawi, farmers demonstrate increased awareness of climate change. However, many farmers associate climate change primarily with rainfall patterns because these directly affect crop production by interfering with planting calendars and activities (Kerr et al., 2018). Moreover, their understanding of the actual causes of climate change varied, with some attributing it to human activity (e.g., cutting down of trees) and others to traditional, cultural, and religious practices (Munthali, Kasulo, and Matamula, 2016).

Understanding perceptions of climate change provides useful insight into adaptation efforts employed by farmers. It is important to note that the causes and effects of climate change and climate variability are a complex subject, and farmer perceptions vary across districts in the same region or country. For example, one study assessing farmers' perceptions of climate variability found that farmers in Bolero, in the Rumphi District of northern Malawi, farmers perceived an increase in temperatures and a decrease in rainfall. Metrological data, however, demonstrated no decreases in rainfall (Munthali, Kasulo, and Matamula, 2016); low crop yields, frequently associated with rainfall decreases, caused farmers to make the association of less rainfall. In another study, general perceptions of increasing temperatures were seen to harm practices like grain-legume rotations, since the change caused farmers to anticipate moisture stress. Conversely, the increasing temperature had a positive effect on mixed farming, which farmers employed as a diversification strategy when they expected low crop yields (Makate, Makate, and Mango, 2017).

Perceptions and knowledge tend to shape farmers' coping and adaptation practices; this is a key observation because it will affect future adoption of recommended strategies or innovations.

5.2. Climate change and variability: historic and future trends

In our climate data analysis, for historical precipitation and temperature trends, we used the Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) and Climate Hazards Group Infrared Temperature with Stations (CHIRTS). For future climate projections we used an ensemble of downscaled Coupled Model Intercomparison Project Phase 5 (CMIP5) (Navarro-Racines et al 2020), specifically the MOHC_HADGEM2_ES, CESM1_CAM5, GFDL_CM3, MPI_ESM_LR, and MIROC_MIROC5 models.

Highlights from a historical climate analysis (covering 1981-2015) suggest that the annual average precipitation in the country is 800-600 mm (Figure 3). The first rainy season, which runs from January to April, is wetter than the second rainy season of November and December. Relatively dry months (< 100 mm of precipitation) are from October to November. January usually receives the highest mean rainfall (approx. 290 mm). In terms of distribution, the Northeastern Region receives significantly higher annual average precipitation (1800 mm) (Figure 4). The South Region also experiences significantly high rainfall and sometimes is affected by tropical cyclones[12] (e.g. Cyclone Idai in March 2019 and Tropical Storm Chedza in January 2015), which bring strong winds, torrential rainfall, and a risk of flooding. The historical annual average temperature over the 1981-2015 period ranged between 17.5o and 30°C (Figure 2). Generally, Malawi has hot rainy seasons, with higher temperatures most common during the wettest months, and cooler dry seasons. Temperatures also vary with altitudes; the northeastern and southern parts of the Central Region are hotter than other parts of Central Region (Figure 4).

The number of consecutive dry days (CDD)[13] serves as an effective measure of extremely low precipitation, seasonal dry spells, and droughts. In the first rainy season, most of the region has experienced CDD around 25 days or lower historically. In the future, the region will experience an overall increase of CDD 5-9 days in season 1[14], suggesting a marginal increase in the incidence of drought throughout the Central Region (Figure 5). Similarly, increases are projected for the number of days with moisture stress (NDWS), which counts the number of days with a ratio of actual to potential evapotranspiration below 0.5. Comparison of historical and future trends in season 1 indicates that moisture stress is predicted to increase across the region, from a historical mean of 79 days up to 100 days in the 2030s and 2050s (Figure 6). Soil moisture is essential for plant processes; thus NDWS serves as an indicator of the available soil moisture for the plants. Higher levels of moisture stress will negatively affect plant growth, nutrient uptake, and other development stages.

Under the projected climate analysis, rainfall variability in the Central Region will exacerbate the uncertainty and instability of crop growing seasons as the start and length of growing seasons will vary across years. Climate information services will become increasingly important to farmers, particularly to inform them of appropriate planting windows

12 https://www.climatestotravel.com/climate/malawi

13 precipitation < 1 mm day-1

14 Season 1 in this study refers to the first wet season occurring in January to April

and varieties. Historically, the start of the growing season (SGLP) in the Central Region has been February (Day 40 of the Gregorian calendar year), with some variability across the region. However, future climate projections suggest that the start of the growing season will move earlier into the year on day 28, an increase of up to two weeks or more. Length of growing season (LGP) is based on the period when the climatic conditions are suitable for crop growth. Historically LGP in the first, long-rains season for the region has been approximately 90 days, while in future it is expected to be shortened by 10 days (Figure 7).

Figure 3. Historical monthly mean temperature and precipitation (average of last 30 years) for the Central region of Malawi. Bars represent total monthly precipitation, whereas lines represent maximum (red line) and minimum (blue line) monthly mean temperatures.

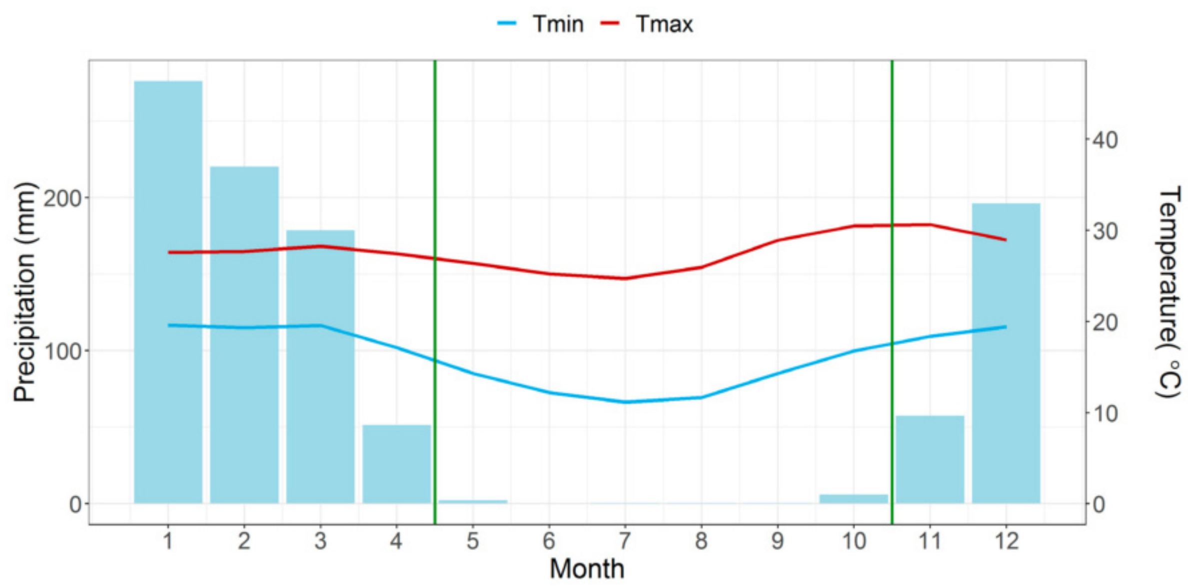


Figure 4. Historical annual mean precipitation and temperature (average of last 30 years) for the Central region of Malawi.

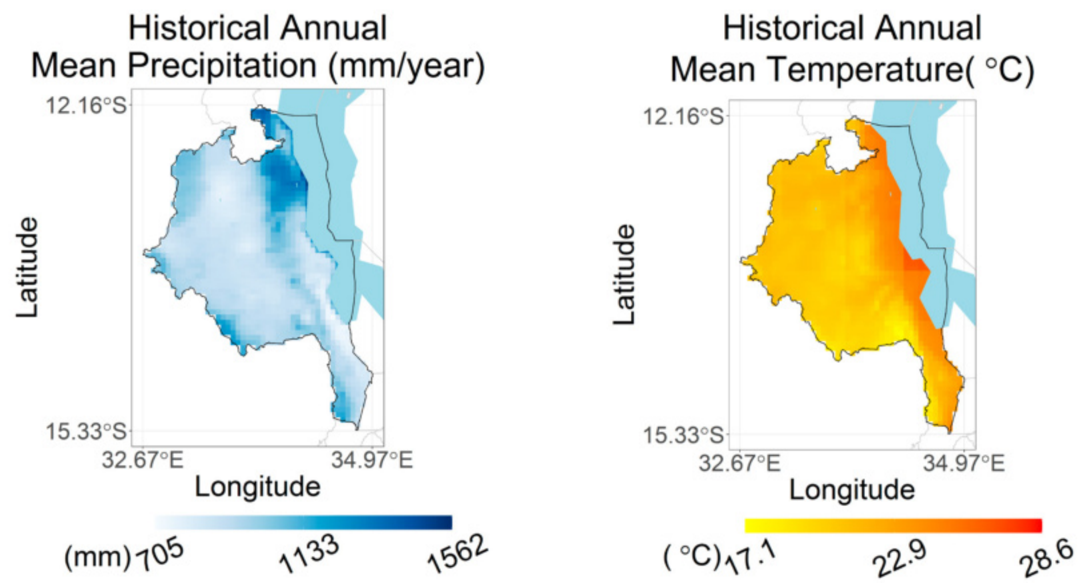


Figure 5. Historical (left), future projected (center) and projected change (right) for the maximum number of consecutive dry days in season 1 (average of last 30 years) for the Central Region of Malawi

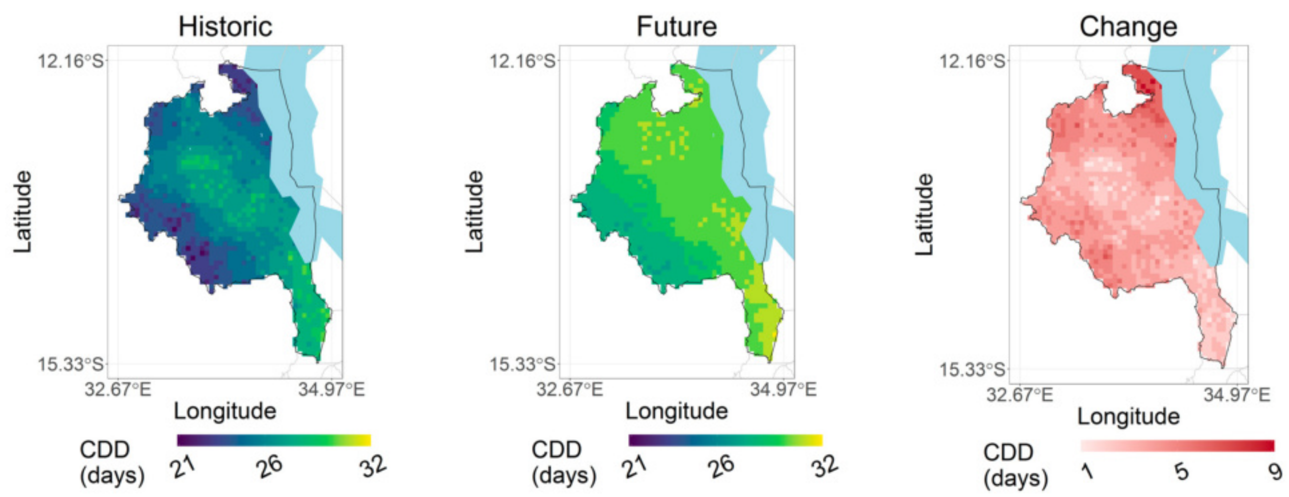


Figure 6. Historical (left), future projected (center) and projected change (right) for the number of moisture stress days in season 1 (average of last 30 years) for the Central Region of Malawi

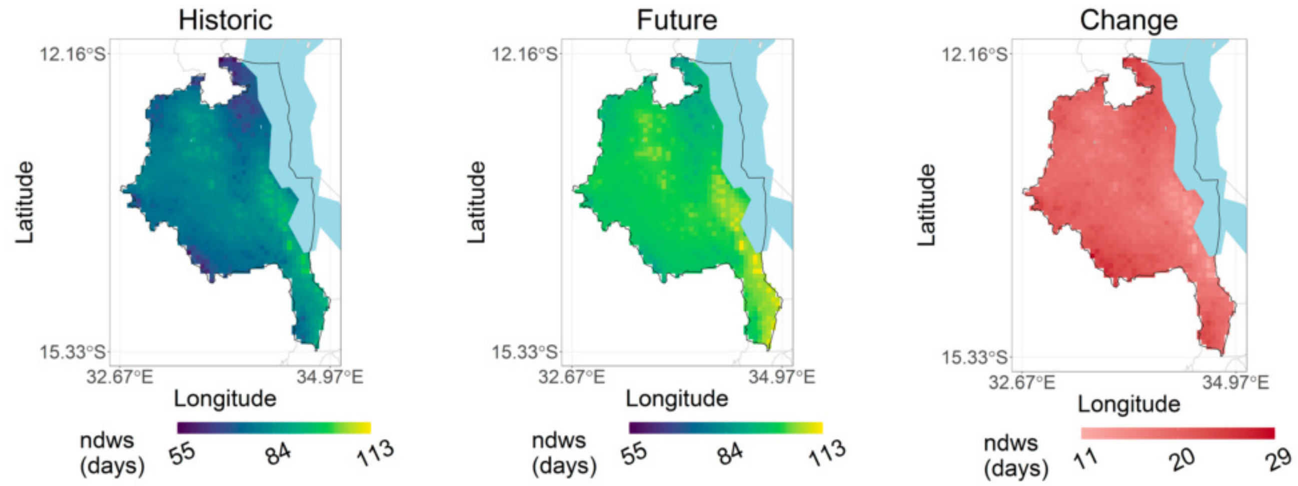
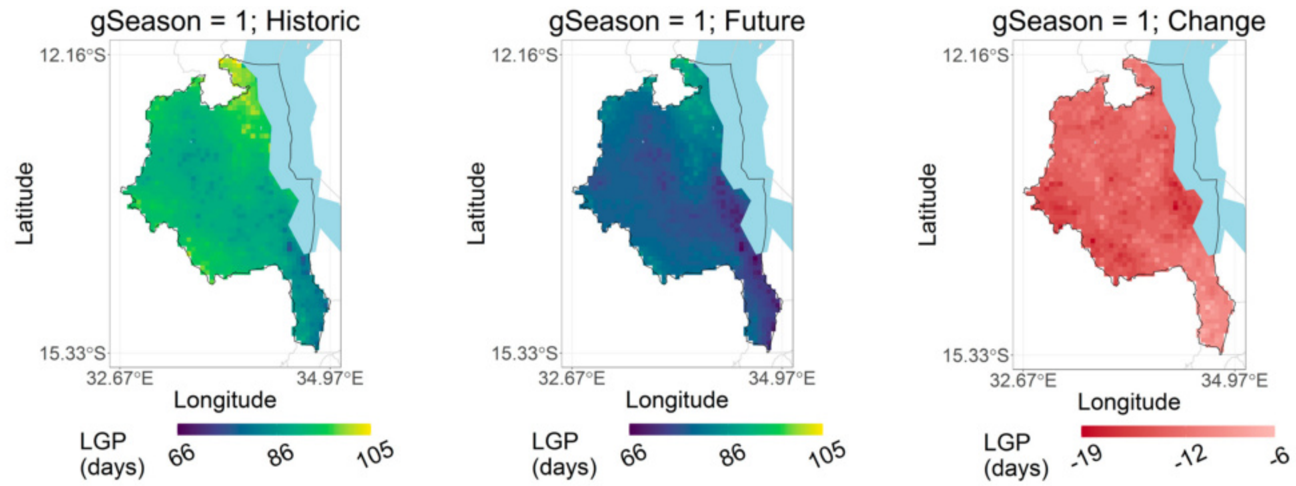


Figure 7. Historical (left), future projected (center) and projected change (right) for the length (days) of the growing season in season 1 (average of last 30 years) for the Central Region of Malawi



5.3. Crop suitability analysis

For the crop suitability analysis, the Eco Crop model (Ramirez-Villegas et al., 2011) was used to find the suitable areas for crop production under current and future climate scenarios. Eco Crop has been used in numerous researches to conduct suitability assessments and to understand the impacts of climate change on many crops. Eco Crop was selected because of 1) ease of implementations and interpretation; 2) its comprehensive database of crop-specific parameters; and 3) its substantial agreement with the climate-change impact projections of other models. The analysis was based on worldclim v1.4 (Hijmans et al., 2005) for the historical/near current climate and an ensemble of 5 downscaled global climate models for the future periods under Representative Concentration Pathway (RCP) 8.5[15] (Navarro-Racines et al., 2020).

The crop suitability analysis[16] indicates generally stable soya bean suitability and increased suitability of peanuts and cassava. Under projected climatic scenarios, there will be a general increase in the suitability of cassava (Figure 8) across all the districts in the Central Region. Some district areas which were historically less suitable (<25%, e.g., Dowa, Lilongwe, and Ntchisi) will increase suitability in the 2030s and 2050s. Soya bean suitability (Figure 10) will remain the same for Nkhotakota, Salima, Kasungu, Lilongwe, and Mchinji districts in the 2030s and 2050s. For the remaining districts, some parts of the district will be more suitable (>20% change). Under climate analysis projections, groundnut production (Figure 9) will become more suitable in the future: for example, Dedza and Ntcheu will have an increase of up to 50%, while Lilongwe, Dowa, and Ntchisi will have an increase in excess of 70% increase from moderate to higher suitability.

5.4. Climate vulnerabilities across agriculture value chain commodities

5.4.1. Cassava

Temperature changes and rainfall variations are key hazards to the cassava value chain. While cassava is relatively tolerant to changing climatic conditions, its yields do decline in response to mean annual temperatures of 12-32°C, high nighttime temperatures, increased dry spells in the growing season, and droughts resulting in water stress. In addition, rainfall and temperature variability during crop development increases the incidence of pest infestations and diseases like Cassava Brown Streak (CBS). Sometimes, interactions among these hazards increase foliar and tuber toxicity, which in turn increases the processing, demands to reduce these toxic levels (Brown, Gleadow, Miller, & Cavagnaro, 2016). Costs of production increase with increasing magnitudes of drought, with the worst outcome being crop failure. Production challenges can result in reduced quality (size and shape, reduced starch levels, shriveling) while low volumes affect processing and prices in the markets. This contributes to food shortages and reduced household incomes.

Poverty continues to constrain the capacity of many rural smallholder farmers to prepare, respond, and recover from these hazards. Women, who dominate many of the cassava production activities, are severely affected. Their poor access to and control of productive resources means that climate impacts disproportionately expose them to food insecurities. The deeply embedded socio-cultural views on women's social, economic, and political status as inferior to that of men exacerbates existing inequities. Education levels also play a role in the adoption of new technologies and practices such as the use of new and improved varieties.

15 One high pathway for which radiative forcing reaches greater than 8.5 W m-2 by 2100 and continues to rise for some amount of time.

16 All projections are under RCP 8.5

Figure 8. Historical and future (scenario RCP 8.5, periods 2030 and 2050) suitability of cassava production in the Central Region of Malawi

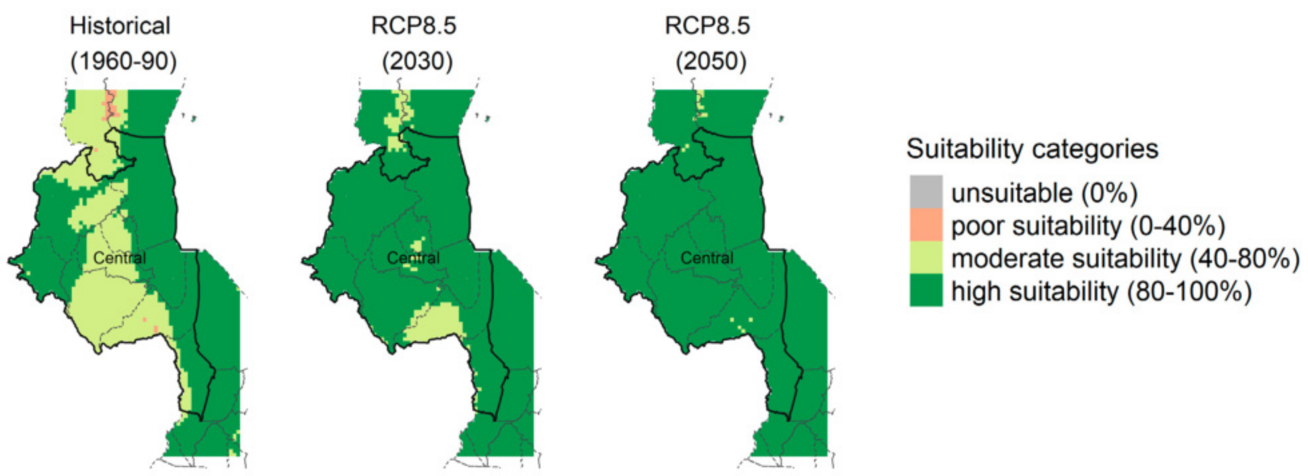


Figure 9. Historical and future (scenario RCP 8.5, periods 2030 and 2050) suitability of peanut production in the Central Region of Malawi

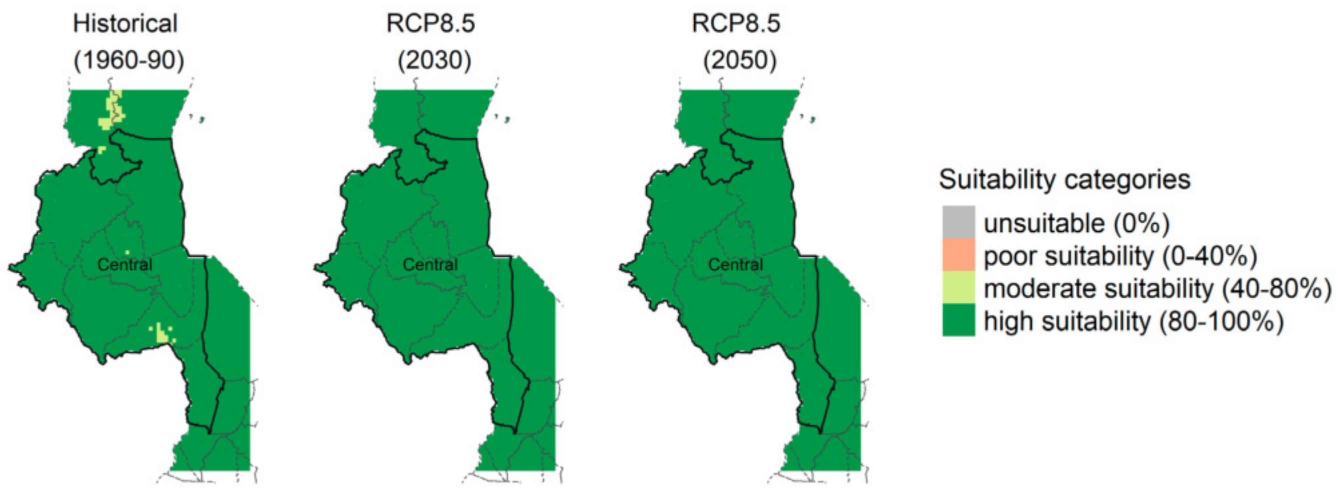
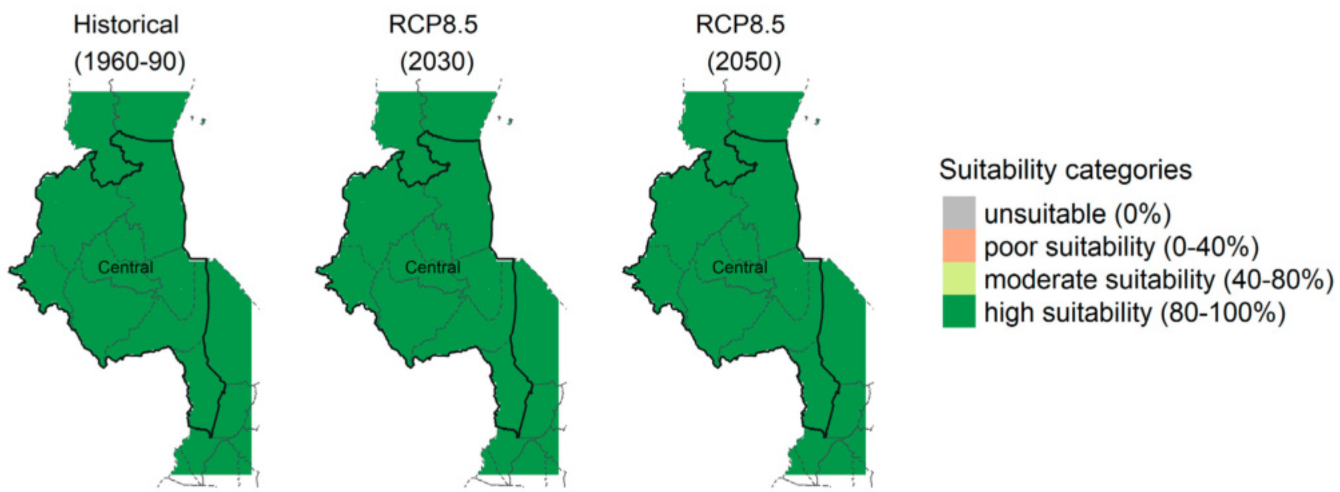


Figure 10. Historical and future (scenario RCP 8.5, periods 2030 and 2050) suitability of soya bean production in the Central Region of Malawi



5.4.2. Peanuts

Because peanuts are sensitive to moisture and temperature changes, decreased general length of rainy seasons and increased dry spells during the growing seasons are serious climatic hazards to their production. Inadequate soil moisture during the critical growth stages of emergence, flowering, pegging, and pod filling leads to poor crop.[17] Moreover, water often improves the use of inputs, for example by increasing the effectiveness of fertilisers and herbicides. Water stresses also contribute to the immaturity of pods which results in poor-quality nuts (bitter or sour flavors, low oil content, smaller size, and poor textures). Other impacts of rainfall variability on peanuts include shifts in planting time and the length of growing seasons, soil infertility, increased pests (e.g. aphids, leafhoppers, cutworms and leaf eaters) and diseases (groundnut rosette virus, groundnut rust, aspergillus infections), increased risk of aflatoxin contamination and decreased yields (Tropical legume farming in Malawi, 2013). Replanting lost crops, additional labor for frequent weeding, and/or urgent postharvest processing in the face of an impending weather event can significantly increase production costs and concomitantly lower profits.

Climactic impacts on the peanut value chain vary widely based on underlying economic, biophysical, cultural, physical, and institutional factors. Farmers who have already adopted available drought-resistant/tolerant peanut varieties are less impacted because they have the economic power to purchase inputs at higher costs or invest in irrigation technologies. Due to the division of value chain activities, men and women are also affected differently. For example, women experience impacts at the on-farm production level, while men, who dominate input supply and marketing, suffer from increased production. Adaptive capacities are enhanced by possession of assets such as mobile phones, radios, bicycles and higher literacy rates, because these things facilitate access to other services like agro-weather information and climate advisories.

5.4.3. Soya beans

The timing, duration, frequency, and severity of increased dry spells in the growing season, along with drought stress, are major climatic hazards affecting soya beans. While soya bean is generally resistant and or tolerant to drought, it is highly susceptible to water deficits during its germination and reproductive stages. Moisture stress affects crucial crop development stages, influencing flowering pod sizes and affecting the seed fill (Mubichi, 2017); increased temperatures during soya bean germination reduces growth rate and yields by disrupting physiological processes that occur during development. Associated pest and disease risks (e.g., cutworm, snout beetle and wireworm; leaf rollers and soya bean rust) are also deterrents to high soya bean yields, leading to major increases in the costs of production and on-farm production processes.[18] While prolonged dry spells are advantageous for peanuts because they increase storage periods, for soya beans, dry spells cause a higher incidence of post-harvest fungal infections (Licht, Wright, & Lenssen, 2013). Similarly, prolonged drought, coupled with high temperatures during maturity, causes pods to shatter and reduces yield to a moderate degree in the post-harvest and marketing stages.

Climate effects on soya beans compound each other. For instance, drought stress leads to increases in production costs, especially rainfall must be supplemented with irrigation; pod abortion results in lower seed production requiring more output for buying seeds or switching to improved varieties. This is in addition to the fact that soya beans produced with inadequate moisture are of lower quality, affecting their post-harvest processing and fetching lower market prices. On-farm production effects primarily impact women, who contribute the most in terms of labor. On the other hand, men are affected by unusually high market prices for inputs. Poor yields affect all actors and farmers due to reduced incomes and food shortages. The severity of impact varies across soya stakeholders based on their place in the chain, the capital they require, and social-cultural and geographical factors. For instance, due to the primacy of women in production and post-harvest activities, they are more affected by the increased costs at these stages.

17 https://pdfs.semanticscholar.org/f1de/158ac6ab55f2e2c49b5d26bc06f0b4798069.pdf
18 http://www.icrisat.org/TropicalLegumesII/pdfs/November-2013.pdf

6. ADAPTATION TO CLIMATE CHANGE AND VARIABILITY

KEY MESSAGES

- Adaptation options to build climate resilience are key for Malawi.
- Malawian farmers already practice crop rotation, double cropping, intercropping, and the use of suitable varieties as adaptation strategies.
- Stakeholders using questionnaires ranked promising strategies presented in this report.
- For peanuts, the best strategies are the use of improved varieties, training in good agricultural practices, the introduction of climate-smart practices and technologies, and water conservation efforts.
- For cassava, best strategies are use of improved varieties and intercropping, as well as post-harvest interventions like improved storage and processing.
- For soya beans, the use of improved and inoculated varieties and increases in post-harvest value-addition are promising adaptation strategies.

6.1. On-farm adaptation strategies

Malawian farmers already have coping strategies to cushion their production against the impacts of climate change.

For soya bean, farmers employ practices like crop rotation with maize, double-legume intercropping with pigeon peas or peanuts, and growing varieties that are suited to the AEZ. Few farmers use fertilizer to boost soil fertility. The Malawi green innovation center promotes new climate resilient and high yielding varieties, seed inoculation and small-scale oil processing. The center also trains farmers on productivity enhancement using sustainable climate-smart approaches.

For cassava, farmers use both bitter and sweet varieties recycled from previous seasons alongside newer, higher yielding, fast maturing, and drought-, water stress, and heat-tolerant varieties. Intercropping of cassava with legumes like pigeon peas is also a common practice used to enhance soil fertility. The cassava value chain has benefited from other interventions such as the introduction of new varieties that are climate resilient and high yielding, processing of cassava flour, creation of market linkages among value chain actors, and the introduction of solar-powered and remote irrigation technologies. For peanuts, farmers apply manure to maintain soil fertility, mulch to reduce runoff and lower soil temperature, and gypsum to improve soil structure through flocculation or aggregation of the soil. Use of water harvesting technologies such as dikes and tied ridges is commonly used for water conservation in dry seasons. Growing fast maturing varieties and employing mixed farming and crop diversification during seasons of erratic rainfall is customary. Small-scale oil processing and introduction of new climate resilient and high yielding varieties, good agricultural practices (GAP) such as crop rotation and conservation agriculture to improve soil quality are strategies promoted by the green innovation center.

Potential adaptation strategies can help farmers cope with the effects of climate change (Table 1). Soya bean farmers can add value by producing soymilk and tofu or by processing crops for feed production for the fish and poultry industries. The adoption of varieties that can grow in all of Malawi's AEZs is recommended. Soya bean inoculation is a critical GAP for optimum yields. Farmers who form associations can achieve supportive partnerships and improved market access.

For peanuts, the promotion of quality seed among peanut farmers can improved yields. Planting peanuts in permanent, sunken planting basins, which serve as water harvesting stations during the dry season; alternatively, peanut straw can be used to conserve moisture. Research has also demonstrated that biological control against aflatoxins is effective for peanuts, so farmers need to be informed and trained on integrated pest and diseases management. While it is generally useful to encourage farmers to use adaptation options such as early maturing and drought-resistant varieties, these can be disadvantage to peanut farmers due to their lower oil content, which is makes these varieties less desirable to processors.

For cassava, incorporation of leaves and stems into the soil after harvesting can help boost soil fertility. Investment in seed multiplication business and the release of heat- and drought-tolerant varieties of cassava can help farmers adapt to climate change. Farmers can employ post-harvest management and processing options such as flour for confectionery purposes. Household-level storage technologies can improve cassava durability. To cushion farmers against drought periods, rainwater storage, drip irrigation systems, and rehabilitation of irrigation schemes are feasible adaptation options. Lastly, farmers require continuous training on new technologies that improve weed control, and manage pests and disease risks, similar to the biological control for aflatoxins in the peanut value chain.

Table 1. Specific practices within each practice group relevant to the focus value chains

PRACTICE GROUPS	CASSAVA VALUE CHAIN	PEANUT VALUE CHAIN	SOY VALUE CHAIN
Climate services		• Capacity building in climate-smart practices and technologies*	• Capacity building in sustainable and climate-smart approaches
Conservation agriculture	• Incorporation of crop residue; Intercropping*	• Conservation agriculture • Mulching	• Conservation agriculture* • Double legume intercropping
Disease & integrated pest management	• Capacity building	• Pest and disease management training such as biological control against aflatoxins	
Fertilizer management	• Fertilizer production		• Fertilizer application
Improved processing	• Improved processing options		

PRACTICE GROUPS	CASSAVA VALUE CHAIN	PEANUT VALUE CHAIN	SOY VALUE CHAIN
Production best practices	• Use of Good Agriculture Practices • Early planting • Capacity building	• Capacity building* • Use of Good Agriculture Practices • Crop diversification	• Soya bean seed inoculation for optimal yields • Use of Good Agriculture Practices • Maize-legume-soya crop rotation
Variety improvement	• Improved, modern seed varieties*; Heat and drought tolerant varieties; Seed multiplication business; Tolerate or resist climate hazards;	• Improved varieties*; Tolerate or resist climate hazards;	• Improved, modern seed varieties*; Improved seed or planting material; Stress-tolerant, disease- and pest-resistant, or nitrogen fixing varieties
Water management	• Rainwater storage • Drip irrigation • Rehabilitation of irrigation schemes	• Water conservation efforts* • Promotion of water management and related infrastructure such as planting in permanent, sunken planting basins that serve as water harvesting stations in the dry season • The use of peanut straw to conserve moisture • Gypsum use to retain moisture • Water harvesting using dikes	
Storage and post-harvest	• Household-level storage technologies* • Value addition flour production for confectionary purposes*		• Value addition soymilk and tofu production* • Production of feed for fish and poultry industries • Investment in small-scale oil processing
Marketing	• Match varieties to consumer market needs	• Match varieties to consumer market needs	• Linking farmers to markets by joining associations and creating partnerships • Match varieties to consumer market needs
Finance			• Provision of loans and credits to smallholders

*Denotes that this is the highest-ranked adaptation strategy for its respective value chain.

6.2. Overall ranking of the adaptation strategies

Stakeholder assessments, conducted using structured questionnaires, identified current and novel adaptations that reduce agricultural risk and help value chain actors adapt to climate change. These experts were sourced from a range of institutions and disciplines (Annex 2). They build on information collected under the climate impact modeling process to identify adaptive strategies. They provide a foundation for understanding both the types and severity of risks to each value chain.

Across the selected commodities, stakeholders agree on the importance of improved seed varieties that are bred both to tolerate or resist climate hazards and to match different consumer market needs. Other promising adaptation options at the input stage include investment in water conservation technologies and the use of efficient irrigation systems to reduce the risks associated with rainfall variability in the Central Region. During on-farm production, they further concur on the use of GAPs, such as intercropping, crop diversification, conservation agriculture, and integrated pest and disease control. Value addition (e.g., processing cassava flour) was noted as a promising adaptation strategy due to its effect on the market value as well (Table 2).

Table 2. Adapting to climate change: strategies across major value chain commodities

SOYA BEAN	INPUT	ON-FARM	POST-HARVEST	MARKETING
Increased dry spells	• Shortage of water • Increased input costs	• Risk of fungal infections risks • Reduced pod size and numbers	• Low quality for processing	• High demand and low supply leads to poor soya farm gate prices
Magnitude of impact	LOW	SEVERE	LOW	MODERATE
Promising adaptation strategies	• Adoption of improved varieties according to production location • Inoculation of soya bean seeds • Application of fertilizer			
Drought	• Shortage of water • Increased input costs	• Pest infestations • Shattering • Reduced yields	• Low quality for processing	• High demand and low supply leads to poor soya bean farm gate prices
Magnitude of impact	LOW	MAJOR-SEVERE	LOW	MODERATE
Promising adaptation strategies	• Adoption of improved varieties according to production location • Inoculation of soya seeds • Double legume intercropping			

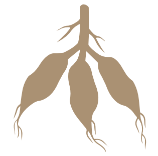
Strategies to mitigate both hazards

Farmers' coping strategies	• Crop rotation with maize • Growing of varieties that are suited specific AEZs • Use of fertilizer to boost soil fertility • Double legume intercropping with pigeon peas or peanuts • Use of traditional knowledge and practices
Potential adaptation strategies	• Introduction varieties that are stress-tolerant, disease- and pest-resistant, or nitrogen-fixing • Use of inoculated seed • Improved agronomic practices • Intensified maize-legume crop rotation • Post-harvest handling technologies • Provision of inputs, loans, and credit to smallholders
Interventions under GICs	• Investments in small-scale oil processing • Introduction of new varieties • Training in a sustainable and climate-smart approaches

PEANUT	INPUT	ON-FARM	POST-HARVEST	MARKETING
Decreased length of rainy season	• Increased cost of inputs • Necessity of buying seeds twice	• Replanting of seeds • Frequent weeding	• Improved varieties have less desirable characteristics at the processing stage	• Low volumes lead to unusually high prices
Magnitude of impact	MODERATE-MAJOR	MAJOR-SEVERE	MAJOR	LOW
Promising adaptation strategies	• Biological control of aflatoxins • Improved varieties • Crop diversification • Mulching and use of gypsum to retain moisture • Water harvesting using dikes			
Increased dry spells	• Increased costs due to re-seeding	• Poor crop establishment	• Peanut Color discoloration • Small sized nuts	• Unusually high market prices
Magnitude of impact	MODERATE-MAJOR	SEVERE	MAJOR	LOW
Promising adaptation strategies	• Biological control of aflatoxins • Conservation agriculture • Improved varieties • Dry planting • Crop diversification • Water harvesting			

Strategies to mitigate both hazards

Farmers' coping strategies	• Mixed farming and crop diversification • Application of manure, mulch, and gypsum	• Water harvesting
Potential adaptation strategies	• Improved varieties • Improved agronomic practices • Technological control for aflatoxins, pests and diseases • Biological control of aflatoxin	• Intensified maize-legume crop rotation • Post-harvest handling technologies • Provision of inputs, loans, and credit to smallholders
Interventions under GICs	• Investments in small-scale oil presses • Introduction of improved varieties	• Promotion of good agricultural practices • Conservation agriculture

 CASSAVA	INPUT	ON-FARM	POST-HARVEST	MARKETING
Drought	• Increased demand for improved varieties	• Decline in yields • Increased disease incidence	• Low volumes • Reduced processing quality • Increased processing costs	• High prices
Magnitude of impact	SEVERE	SEVERE	LOW	MODERATE
Promising adaptation strategies	• Improved varieties • Investment in seed multiplication • Irrigation technologies • Improved processing options			
Increased dry spells	• Increased demand for improved varieties	• Decline in yields • Increased disease incidence • Increased tuber toxicity	• Low volumes • Reduced quality • Increased processing costs	• High prices
Magnitude of impact	SEVERE	SEVERE	LOW	MODERATE
Promising adaptation strategies	• Early planting • Growing improved varieties • Improved storage technologies • Irrigation technologies • Improved processing options			

Strategies to mitigate both hazards	
Farmers' coping strategies	• Use of both bitter and sweet varieties • Recycling seed from previous seasons • Intercropping with legumes like pigeon peas • Use of improved varieties • Traditional processing of cassava into fermented flour
Potential adaptation strategies	• Training farmers on good agronomic practices • Introduction of improved varieties • Improved storage technologies • Production of special fertilizer blends • Manual for improved soil and crop management practices • Support for farmers with planting materials
Interventions under GICs	• Provision of improved cassava seeds • Processing of cassava flour • Market linkage among value chain actors • Introduction of irrigation technologies

6.3. Cost benefit analysis of the prioritized adaptation strategies

A cost-and-benefit analysis (CBA) is critical when making investment decisions, including those associated with CSA practices. This is because CBA allows for the comparison of costs and returns associated with a given CSA practice when compared to existing practices, or the business as usual (BAU) state of affairs (Ng'ang'a et al., 2017). There are three important CBA indicators.[19] The Net Present Value (NPV) measures the incremental flow of net benefits over an innovation's life cycle; the Internal Rate of Return (IRR) is the rate, which sets NVP to 0, which means that a higher IRR indicates a higher profitability potential; the payback period, or the number of years it takes to recoup the initial investment in an innovation.

We used structured questionnaires to acquire detailed information on variables used for this CBA analysis. The stakeholders interviewed were pooled from varied institutions working in and with farmers in the cassava and peanut value chains. Only cassava and soya beans were prioritised for this analysis.

The CBA was computed for the two highest-ranked innovations overall: improved, modern seed varieties for cassava and improved, modern seeds combined with conservation agriculture for soya bean and the results are summarized in Table 3. In both value chains, improved seed varieties were prioritized because of the resulting plants' ability to conserve water, reduce demand for labor, and produce high yields. Conservation agriculture was prioritized because of its potential to conserve water, reduce labour demand, and provide superior yields. Both cassava and soya beans had a lifecycle of six years. The three innovation requires a larger capital for their implementation, maintenance and operation as compared with the BAU. The implementation and maintenance of new improved seeds for both the cassava and rice value chains require more than 18% of the capital that is needed in for BAU (Table 4). The implementation of conservation agriculture requires 5% more capital for implementation and maintenance as compared to BAU (Table 5). The main benefit associated with the use of improved seeds for soya beans and cassava value chain, and the use implementation of conservation agriculture in soya beans, therefore, emanated from increased yield (Figure 11).

The NPV for improved varieties of cassava seeds was, on average,[20] 8,975 USD per hectare, an average IRR of 308% (Table 3). The improved seed varieties and conservation agriculture for soya beans value chain had an average NPV of about 1100 USD and 508 USD per hectare respectively. The IRR for conservation agriculture and improved seeds in the rice value chain was about 500% (Table 3), which is higher than the prevailing discount rate of 13.5%. All the three innovations had a payback period of 1 year, where payback period refers to the time needed to repay the initial investment. A longer payback act as a barrier for adoption and scaling up of innovations.

The three innovations on average are both profitable and have a minimum financial risk for farmers, meaning that it is very unlikely that these innovations will give negative or unprofitable results in any given year. Even in the case of using improved seed variety for cassava and soya beans value chains that shows some level of risk (Table 3) do to the high installation and implementation costs (Table 4), these innovations constitute a promising basket of innovations.

Risks were modelled using the Monte Carlo

19 The NPV measures the incremental flow of net benefits from the innovation over its lifecycle, while the IRR is the discount rate that equates NPV to 0. A higher IRR indicates a high profitability potential. Payback period is the number of years it takes to recoup the initial investment.

20 On average because we used data from two farmers whose cassava production yielded different returns per hectare

simulation (at n=10000 simulations), showing low risks for cassava and soya beans. The probability distribution of the NPV for the three innovations evaluated are summarized in Table 3. The analysis illustrates the profitability risk related to implementing each of the three innovation given the characteristics of the cumulative density function of expressing the probability of the NPV of being less than or equal to the costs of adopting each innovation (i.e. implementation, maintenance and operation costs in this case). Improved seed varieties for cassava are a low-risk investment because the probability of losing the invested money is only about 5.5%. For soya beans, the risk of losing invested money is about 9% while investing in conservation agriculture for soya beans carries no risk at all (Column 6 in Table 3).

Table 3. Summary Information on Profitability of Prioritized Innovations in Malawi.

VALUE CHAIN	INNOVATION	PROFITABILITY INDICATORS			
		NPV IN US$	IRR IN (%)	PAYBACK PERIOD (YEARS)	RISKINESS OF INVESTMENT
Cassava	New improved variety of seeds	8,975	308 (>r)	1	This innovation has a 5.5% probability of making unprofitable returns on average
Soya bean	New improved variety of seeds	1100	516 (>r)	1	This innovation has 9% probability of making unprofitable returns
Soya bean	Conservation agriculture	508	493 (>r)	1	This innovation has no likelihood of making unprofitable returns

NB: >r indicates that the practice is privately profitable on a per hectare basis. All computation has been done per hectare basis.

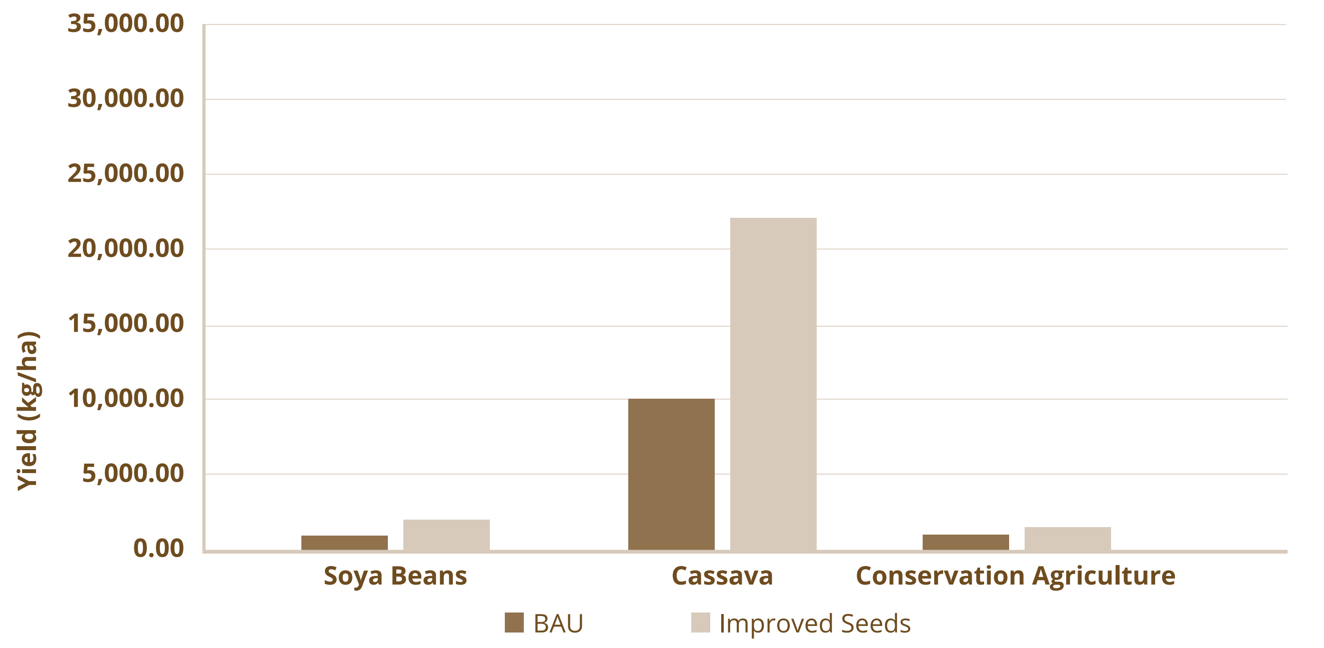
Table 4. Summary Information on Installation cost for business as usual (BAU) and the new improved seed variety in soya bean value chain

CSA PRACTICE	INSTALLATION COSTS (US$/HA)			MAINTENANCE COSTS (US$/HA)			OPERATION COSTS (US$/HA)		
	BAU	NEW IMPROVED VARIETY OF SEEDS	*% CHANGE IN COST*	BAU	NEW IMPROVED VARIETY OF SEEDS	*% CHANGE IN COST*	BAU	NEW IMPROVED VARIETY OF SEEDS	*% CHANGE IN COST*
Soya beans	341	403.6	*+18*	974.5	1136	*+18*	327	387	*+18*
Cassava	1112	2029	*+82*	4079	6682	*+82*	682	1458	*+82*

Table 5. Summary Information on Installation cost for business as usual (BAU) and conservation agriculture in Soya bean value chain

VALUE CHAIN	INSTALLATION COSTS (US$/HA)			MAINTENANCE COSTS (US$/HA)			OPERATION COSTS (US$/HA)		
	BAU	CONSERVATION AGRICULTURE	*% CHANGE IN COST*	BAU	CONSERVATION AGRICULTURE	*% CHANGE IN COST*	BAU	CONSERVATION AGRICULTURE	*% CHANGE IN COST*
Soya beans	405	424	*+5*	945	891	*-6*	103	184	*+79*

Figure 11. Yield for Business as usual versus the innovations



CBA is a very important tool for evaluation of investment that requires a decision to be made, especially when the resource to support such an endeavour are in the offing. Despite the strength and limitation (i.e., potential inaccuracies when identifying and quantifying costs and benefits and hence NPV) associated with CBA methodology, this kind of analysis is important for planning and investment decisions. The three innovations considered in this report are ‘no-regret options’, implying that they will yield economic benefits now and in the future and are therefore important for strengthening future household resilience. The three innovation studied are profitable, have a high IRR and a short payback period, and these could explain why this innovation emerged as strong choices for stakeholders during the prioritization process. When the distribution of the NPV indicator is considered, all the three practices have a low risk of being unprofitable, despite the high implementation and maintenance costs, demonstrating an economic case for their scaling up. This is very important given that GIC is interested in identifying innovations that can produce desirable outcomes for a majority of smallholder farmers in Malawi.

7. SYNTHESIS AND RECOMMENDATIONS

Climate change will bring altered rainfall patterns to Malawi; increased dry spells within growing seasons and decreased general lengths of growing seasons are important climatic hazards in the production of peanuts, cassava, and soya bean. It is, therefore, imperative for farmers to take proactive measures against these adverse impacts. Accordingly, farmers require constant training and increased access to productive resources, information, knowledge, and practical skills to enable them to make informed decisions and recognize risks and better market opportunities. All interventions to enhance farmers' resilience should take into account the local contexts, social norms, and farmers' needs, demands, and priorities. They should also promote sustainability and equity.

Investing in an enabling environment is an essential prerequisite for the transformation of the cassava, peanut, and soya bean value chains. This means that extensive stakeholder engagements, gender considerations, efficient policy and institutions, infrastructure (e.g. roads), and the linkage of research and data to informed decision-making are all necessary. Efforts in these areas will accelerate the adoption of proposed adaptation strategies. Mainstream agriculture and development policies need to include specific, short- and long-term interventions that guide farmers' resilience. Malawian policymakers should use inclusive and participatory approaches to ensure buy-in by decision-makers and people whom their decisions might affect, namely farmers, civil societies, the private sector, or investors. In general, policies should not disincentivize or constrain ongoing or future interventions. They should also be dynamic, subject to ongoing review to remain effective and to address the evolving complexities of climate change.

Similarly, there need to strengthen institutional coordination for climate change-related efforts in Malawi. Climate is ever changing and is crosscutting in nature; adaptation requires multi-pronged approaches across sectors to tackle it. Insufficient coordination encourages duplication of efforts and disharmony in supporting farmers. This is because different actors can provide opposing information, which in turn confuses farmers and becomes a disincentive. Therefore, coordinating mechanisms must be put in place to guide all types of organizations on working with communities in a way that drives positive changes.

Going forward, a variety of opportunities for collaboration, funding, and synergies exist for these practices (Table 6). Several organizations are well positioned to offer general support across many potential activities. For example, Malawi's National Agriculture Policy works in conservation agriculture, disease and integrated pest management, production best practices, storage and post harvest technologies, water management, and finance services. Several federal policies broadly address climate change adaptation and mitigation, including Malawi Vision 2020, Malawi Poverty Reduction Strategy, Malawi Growth and Development Strategy, National Environmental Policy, National Climate Change Investment Plan, National Adaptation Programme of Action, and the National Climate Change Management Policy. The Malawian Government is collaborating with several international institutes on climate resiliency programming, such as the Consultative Group on International Agricultural Research, International Institute of Tropical Agriculture, National Smallholder Farmers' Association of Malawi, The Clinton Development Initiative, International Crop Research Institute for the Semi-Arid Tropics, United States Agency for International Development, International Potato Centre, the Group on International Agricultural Research, and the German Society for International Cooperation.

Further, several barriers challenge the general implementation of climate-aware policy in Malawi. Some of the national policies lack clear entry points and guidelines for specific areas like agriculture, which limits the ability to implement new approaches and technologies and creates an uncoordinated adaption effort. Limited coordination and collaboration between government, organizations, and institutions have constrained the effectiveness and impact of some efforts. Overlapping and conflicting mandates at different institutions can create roadblocks and duplication of efforts. Gender norms, traditions, and economic status make it difficult for women to be equal partners in agriculture. Poverty exacerbates the ability to adopt new technologies and strategies and creates farmer vulnerability to market volatility and consequent fluctuations in the prices of food and other agricultural inputs and outputs. Infrastructural constraints continue to hinder market access.

Table 6. Practice-group specific potential strategies and considerations for advancing CSA at scale

PRACTICE GROUP	PARTNERSHIPS	BARRIERS	EXISTING AND POTENTIAL FUNDING**	SYNERGIES**
Climate services	• Malawi Vision 2020 • Malawi Poverty Reduction Strategy • Malawi Growth and Development Strategy • National Environmental Policy • National Climate Change Investment Plan • National Adaptation Programme of Action • National Climate Change Management Policy	**Farm level barriers:** • Confidence in weather forecasts • Limited access to forecasts **Institutional barriers:**** • Low access to information and extension services	• Public and private interests with good blended finance potential	• Supports efficiency and planning in input provision, production, post-harvest transport and processing, and marketing
Conservation agriculture	• Malawi Poverty Reduction Strategy • National Agriculture Policy • Malawi Growth and Development Strategy	**Farm level barriers:**** • Considerable capital required • Lack of access to technology • Knowledge gap • Poor energy access creates competing needs for organic residues** **Institutional barriers:**** • Inconsistent extension services • Poor financial service availability	• Good potential for green blended finance, using public funds as a de-risking instrument, delivered through cooperatives to support farmer-initiated investments in long-term land productivity	• Improved soil fertility improves harvest yields, water retention, and climate resiliency. This in turn supports improved water management and robust, stable markets.
Disease & integrated pest management	• International Institute of Tropical Agriculture • United States Agency for International Development • Malawi Bureau of Standard	**Farm level barriers:**** • Knowledge gaps • Financial constraints **Institutional barriers:** • Inconsistent extension services • Poor financial service availability	• Good potential for green blended finance, using public funds as a de-risking instrument, delivered through cooperatives to support farmer-initiated investments in long-term land productivity	• Supports both productivity and environmental/ land restoration goals
Fertilizer management	• Natural Disaster Risk Management Plan	**Farm level barriers:** • Knowledge gaps • Financial constraints **Institutional barriers:** • Inconsistent extension services • Poor financial service availability	• Good potential for green blended finance, using public funds as a de-risking instrument, delivered through cooperatives to support farmer-initiated investments in long-term land productivity	• Supports climate resiliency and yields, maximizes cost efficiency of fertilizer inputs, and minimizes environmental impacts • Supports robust markets
Improved processing	• Farmer's Unions • Farmer's Union of Malawi • National Smallholder Farmers' Association of Malawi	**Farm level barriers:** • Knowledge gaps • Financial constraints **Institutional barriers:** • Lack of training • Weak management structures in cooperatives and associations lock farmers out of beneficial opportunities	• High potential for private sector investing	• Best processing practices reduce losses in storage and in transport to market, thus stabilizing supplies
Production best practices	• Malawi Poverty Reduction Strategy • National Agriculture Policy • Malawi Growth and Development Strategy • International Institute of Tropical Agriculture • International Crop Research Institute for the Semi-Arid Tropics • Feed the Future • International Potato Centre	**Farm level barriers:** • Knowledge gaps • Financial constraints • Limited use of inputs • Limited mechanization **Institutional barriers:** • Inconsistent extension services • Weak finance services • Weak policy support**	• Blended finance, using public funds as a de-risking instrument, delivered through cooperatives to support farmer-initiated investments in long-term land productivity	• Supports climate-resiliency and yields, thus improving market stability

PRACTICE GROUP	PARTNERSHIPS	BARRIERS	EXISTING AND POTENTIAL FUNDING**	SYNERGIES**
Variety improvement	• International Institute of Tropical Agriculture • Agro-Input Suppliers Limited • Ministry of Agriculture • Farmers' representative bodies • Farmer's Union of Malawi • National Smallholder Farmers' Association of Malawi • The Clinton Development Fund • The Agricultural Technology and Clearing Committee • Feed the Future • International Crop Research Institute for the Semi-Arid Tropics • International Potato Centre • Department of Agricultural Research Services • Farmer's Associations	**Farm level barriers:** • Financial constraints • Considerable capital required • Limited availability • Some financial risk involved in adopting improved varieties **Institutional barriers:** • Inadequate access to inputs • Low access to finance • A poorly harmonized seed approval process disincentivizes seed companies from investing in the development of seeds and markets • Knowledge gaps • Gendered social dynamics result in different access for men and women along the value chains • Lack of research and development and distribution networks**	• International research funding offers robust support • Diversification toward local and culturally important crops needed	• Climate-resilient varieties help stabilize harvest quantities, thus supporting stable markets
Water management	• Malawi Poverty Reduction Strategy • National Agriculture Policy • Natural Disaster Risk Management Plan	**Farm level barriers:** • Financial constraints • Knowledge gaps **Institutional barriers:** • Lack of access to training and technology • Considerable capital required	• Public and private interests with good blended finance potential	• Effective water management reduces erosion and flooding to support productivity and land restoration efforts
Marketing		**Farm level barriers:** • Poor transportation networks to access markets **Institutional barriers:** • Lack of infrastructure	• High potential for private sector investing	• Stable markets enable long-term contracts, competitive pricing, consumer demand determining supply, and international trade engagement
Finance	• National Agriculture Policy	**Farm level barriers:** • Limited access • Knowledge gaps **Institutional barriers:** • Poor access to credit • Poor availability of farmer-targeted financial services • Low involvement on private sector**	• Blended finance, using public funds as a de-risking instrument, delivered through cooperatives to support farmer-initiated investments in long-term land productivity	• Enable on-farm investments in soil fertility, optimized management techniques, and climate resiliency
Storage and post-harvest	• National Agriculture Policy • International Institute of Tropical Agriculture	**Farm level barriers:** • Capital constraints • Knowledge gaps **Institutional barriers:**** • Suboptimal infrastructure, including inadequate access to good roads, cold storage, warehouses, and other conservation technologies	• High potential for private sector investing	• Reduces losses, thus increasing profits and supporting markets stability, particularly inter-seasonally

** based on literature

8. WORKS CITED

AGRA Malawi Operational Plan. (2020). Retrieved from AGRA: https://agra.org/wp-content/uploads/2017/12/agra-malawi-final.pdf

Chipeta, M. (2013). Status of cassava (Manihot esculenta) production and utilization in Malawi. International Journal of Agronomy and Plant Production, 4, 3637-3644.

Grist, N. (2015). Malawi's Agriculture, Climate Change and Food Security Country Analysis and Programming Recommendations. Evidence on Demand.

Kaitano, V., & Martin, A. (2009). GENDER AND DIVERSITY ISSUES RELATING TO CASSAVA PRODUCTION AND PROCESSING IN MALAWI. C:AVA, Lilongwe. Retrieved from https://www.nri.org/images/documents/development-programmes/gender_soc_dif/publications/Malawi_GDSituationalAnalysis.pdf

Kananji, G. A., Yohane, E., Siyeni, D., Kachulu, L., Mtambo, L., Chisama, B. F., Mulekano, O. (2013). A Guide to Soybean Production in Malawi. Lilongwe: Department of Agricultural Research Services. Retrieved from http://os.aiccafrica.org/media/Guide%20to%20Soybean%20Production_finale.pdf

Kerr, R. B., Nyantakyi-Frimpong, H., Dakishoni, L., Lupafya, E., Shumba, L., Luginaah, I., & Snapp, S. S. (2018). Knowledge politics in participatory climate change adaptation research on agroecology in Malawi. Renewable Agriculture and Food systems, 238-251. doi: https://doi.org/10.1017/S1742170518000017

Kirui, O. K. (2016). Economics of Land Degradation and Improvement in Tanzania and Malawi. In T. Johnson, W. Anderson, E. Nkonya, A. Mirzabaev, & J. V. Braun (Eds.), Evaluating Global Land Degradation Using Ground-Based Measurements and Remote Sensing (pp. 609-649). Springer.

Kocke, S. (2019). The Perception of Cassava in Malawi: A Literature Study About a Root Crop's Implication on Food Security in the Past and the Present. Master's thesis in Global Environmental History. Retrieved from http://www.diva-portal.org/smash/get/diva2:1384180/FULLTEXT01.pdf

Lwanda, M., Maonga, B., Phiri, S., & Gondwe, S. (2012). Analysis of Business Performance of agricultural cooperatives: A case study of Ngolowindo, Nsangu and Chitsanzo Cooperatives in the Central Region of Malawi. Lilongwe.

Makate, C., Makate, M., & Mango, N. (2017). Smallholder Farmers' Perceptions on Climate Change and the Use of Sustainable Agricultural Practices in the Chinyanja Triangle, Southern Africa. (F. Witlox, & M. J. Bull, Eds.) Social Sciences, 6(1). doi: https://doi.org/10.3390/socsci6010030

Malawi Government. (2008). State of plant genetic resources for food and agriculture.

Matita, M. (2018). (L. White, Editor) Retrieved June 10, 2020, from Future Agricultures: https://www.future-agricultures.org/blog/groundnut-marketing-in-malawi-a-review-of-vendors-experiences/

Mubichi, F. M. (2017). A comparative study between Mozambique and Malawi soybean adoption among smallholder farmers. Journal of Rural Sciences, 1(32), 21-39.

Munthali, C. K., Kasulo, V., & Matamula, S. (2016). Smallholder farmers perception on climate change in Rumphi District, Malawi. Journal of Agricultural Extension and Rural Development, 8(10), 202-210. doi: https://doi.org/10.5897/JAERD2016.0798

National Statistical Office. (2015/16). Demographic and Health Survey: Child Health fact sheet. Malawi Government.

National Statistical Office. (2016/17). Census of Economic Activities Report. Malawi Government.

National Statistical Office. (2020). Monthly Statistical Bulletin January 2020. Government of Malawi.

Penrhys-Evan, T. (2018). Groundnut commercialisation trends in Malawi. Retrieved June 10, 2020, from Future Agricultures: https://www.future-agricultures.org/blog/groundnut-commercialisation-trends-in-malawi/#:~:text=Groundnut%20is%20the%20most%20important,%%20of%20total%20production%20marketed

Tropical legume farming in Malawi. (2013). A bulletin of the tropical legumes II project, p. 14.

World Bank. (2017). Retrieved June 9, 2020, from World Bank Data: https://data.worldbank.org/indicator/NV.AGR.TOTL.ZS?locations=MW

Navarro-Racines, C., Tarapues, J., Thornton, P. et al. (2020). High-resolution and bias-corrected CMIP5 projections for climate change impact assessments. Sci Data. 7, 7.

Ramirez-Villegas, J., Jarvis, A. & Läderach, P. (2013). Empirical approaches for assessing impacts of climate change on agriculture: the EcoCrop model and a case study with grain sorghum. Agric. For. Meteorol. 170, 67–78 .

World Trade Organization – Trade Profiles. (2020). https://www.wto.org/english/res_e/statis_e/daily_update_e/trade_profiles/MW_e.pdf

Uncertainty reduction in models for understanding development applications (UMFULA). (2018). Gender, agriculture and climate change in Malawi https://media.africaportal.org/documents/gender-agriculture-climate-services-brief-umfula-final.pdf

Laurence Mathieu-Colas, Goulven Le Bahers, Laston Maxwell Makina (2009). Crop management, Roots and tubers, Trainers guidelines.

9. ACKNOWLEDGMENTS

This study was conducted by the Alliance of Bioversity International and International Center for Tropical Agriculture (CIAT), under the CGIAR Research Program on Climate Change, Agriculture, and Food Security (CCAFS), supported by the Green Innovation Centres for the Agriculture and Food Sector (GIC) implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) under the framework of the special initiative "ONE WORLD – No Hunger" on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ).

The document has been developed by Ivy Kinyua under the technical leadership of Stephanie Jaquet, Caroline Mwongera, Stanley Karanja and Evan Girvetz and with contributions from the climate modelling team: Harold A.E. Achicanoy, Alejandra Esquivel, Aniruddha Ghosh, Julian Ramirez-Villegas and the agricultural economics team: Devinia Akinyi, Dorcas Jalango, George Kanyenji, Bwema Ombati.

We acknowledge the contribution of the project manager for GIZ: Bjoern Hecht, Heike Herden and of the GIC team in Malawi: Rodney Gondwe.

Technical review and editing: Annalese Duprey, Stephanie Pentz, Mehrey Vaghti, and Megan Mayzelle

Infographics and layout: Katya Kuzi

This document should be cited as:

Bioversity International & CIAT, CGIAR CCAFS, and GIZ. 2020. Adapting Green Innovation Centres to Climate Change: Analysis of value chain adaptation potential. Cassava, Peanut, and Soya Bean Value Chains in the Central Region of Malawi

Alliance

Bioversity International

CIAT
International Center for Tropical Agriculture
Since 1967 Science to cultivate change

giz Deutsche Gesellschaft
für Internationale
Zusammenarbeit (GIZ) GmbH

CGIAR

RESEARCH PROGRAM ON
Climate Change,
Agriculture and
Food Security

CCAFS